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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

ALTITUDES

BETWEEN

LAKE SUPERIOR AND THE ROCKY MOUNTAINS

BY

WARREN UPHAM

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY, GLACIAL DIVISION,
Madison, Wisconsin, August 4, 1890.

SIR: I have the honor to transmit herewith manuscript for a bulletin on "Altitudes between Lake Superior and the Rocky Mountains," prepared by Assistant Geologist Warren Upham. The value of the arge mass of data contained is obvious.

Very respectfully,

T. C. CHAMBERLIN,
Geologist in charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

ALTITUDES BETWEEN LAKE SUPERIOR AND THE ROCKY MOUNTAINS.

By Warren Upham.

INTRODUCTION.

In the survey of Lake Agassiz, a preliminary report of which forms Bulletin No. 39, it was found necessary to ascertain the altitudes determined within its area by railroad surveys as the basis for leveling along the shore lines of that glacial lake, and learning their relations in height to each other, to the great lakes of the St. Lawrence and Nelson Rivers, and to the ocean. From the time of the first observations and description of the upper beaches of Lake Agassiz by the author in 1879 and 1881, for the Geological Survey of Minnesota, and especially since the work was extended in 1885, under the U. S. Geological Survey, to include both sides of this lacustrine area in Minnesota and North Dakota now drained by the Red River of the North, much attention has been given to this collection of altitudes, and to the means of referring them to the sea level. The greater part of Lake Agassiz, however, was in Manitoba and adjacent British Territory, stretching north to the Saskatchewan; and in 1887, jointly for the Geological Surveys of the United States and of Canada, the author continued his examination of the beaches and deltas on the west side of the lake along a distance of a hundred miles north from the international boundary, across the prairie region of southwestern Manitoba, the leveling in this work being based on the altitudes of the Canadian Pacific Railway and its branches and connecting railways.

When it was decided to publish these notes of altitudes in a separate bulletin for convenient reference, their area was somewhat extended, to cover the natural district between Lake Superior and the Rocky Mountains. The list of railroads here tabulated includes a few lines, mostly built within recent years, in northern Michigan and Wisconsin, every railroad line of Minnesota and North and South Dakota, nearly all in Montana, several lines in northern Iowa, and one in northern Nebraska

and Wyoming. Three lines which lie partly in Minnesota and South Dakota are noted through Iowa, Illinois, and Missouri, to Chicago, Burlington, and St. Joseph, each giving important connections at its southern end with leveling from the sea; and the Northern Pacific Railroad is similarly given in its whole extent westward through Idaho, Oregon, and Washington. In the Dominion of Canada the entire railway system from Port Arthur, on Lake Superior, to Vancouver, on the Pacific, is presented; but a portion of the Canadian Pacific profile in British Columbia requires revision for the elimination of an error of about 40 feet, which can probably be detected only by leveling.

The aggregate length of these railroads is about 18,500 miles. Nearly two-thirds have been noted by the author from the original profiles, kindly submitted to his examination in the offices of the railroad engineers, chiefly in St. Paul, Minneapolis, and Winnipeg; and in stating the sources of information for the several lines, these are distinguished as derived "from profiles." The other lines of which data have been obtained by correspondence, being copied from the profiles or notebooks by the engineers or their assistants, are credited to them directly.

All the altitudes of stations, summits and depressions of grade, bridges, and other points on railroads, refer to the top of the rail. The depth cut, or the altitude of the natural surface, is also generally stated at summits, and at the crossings of the principal streams the stages of low and high water are recorded in all cases where they could be obtained. For better identification of the localities, and for convenience in comparing them and determining their connecting gradients, the distances of all the points noted are given in miles and tenths, usually from one of the termini of the line or of its railroad system.

Three series of levels, connecting this district in the center of the continent with the sea, namely, by the United States Lake Survey from the Atlantic Ocean at New York, by the Mississippi River Commission from the Gulf of Mexico, and by the Northern Pacific Railroad to the Pacific Ocean, agree within 2 feet at St. Paul, and this, after the Lake Superior level, may be regarded as the most important datum for referring most of these series of altitudes to the ocean. The mean height of Lakes Michigan and Huron above mean tide sea-level is determined, according to Maj. A. Mackenzie, of the Corps of Engineers, United States Army, as 581·28 feet by the Lake Survey, and 580·83 feet by the Mississippi River Commission. Accepting the former, the mean altitude of Lake Superior from November, 1870, to January, 1888, derived from Lake Huron by leveling at the Sault Ste. Marie, is 601·56 feet, or approximately 602 feet. This is taken as the plane of reference for the Northern Pacific Railroad, the Canadian Pacific Railway, the St. Paul and Duluth Railroad, and their branches. Besides the three series of leveling already mentioned, by which the altitude of extreme low water (in 1864) of the Mississippi River at St. Paul is obtained, several

other determinations of this datum by railroad surveys from Lakes Superior and Michigan are placed after these in the following table:

Determinations of the altitude of low water of the Mississippi River at St. Paul.

	Feet above mean sea-level.
From the United States Lake Survey, Lake Superior being 602 feet, according to Maj. C. J. Allen, of the United States Engineers, St. Paul (Annual Report of the Chief of Engineers, U. S. Army, for 1881, p. 1813)	683·04
From the Mississippi River Commission and the continuation of its levels to St. Paul (letter of Maj. A. Mackenzie, of the United States Engineers, Rock Island, dated January 23, 1888)	684·75
From the Northern Pacific Railroad surveys, by connection of its series of levels with mean tide of the Pacific Ocean at Tacoma (according to profiles in the Northern Pacific engineer's office, St. Paul)	685
From original surveys for the Lake Superior and Mississippi (now the St. Paul and Duluth) Railroad (notes of J. T. Sewall, surveyor, March, 1863)	683
From the St. Paul and Duluth Railroad profile used in the construction of the road	680·5
From the St. Paul and Duluth Railroad profile, new leveling in 1887 along its entire extent	683
From profiles of the Northern Pacific and the St. Paul and Northern Pacific Railroads, by way of Brainerd	684
From profiles of the Northern Pacific, the Northern Pacific, Fergus and Black Hills, and the St. Paul, Minneapolis and Manitoba Railroads, by way of Wadena, Fergus Falls, and St. Cloud	683
From Lake Superior by the Chicago, St. Paul, Minneapolis, and Omaha Railway profile	686
From Lake Superior by the Minneapolis, Sault Ste. Marie, and Atlantic Railway profile	680
From Lake Michigan by the Chicago, St. Paul, and Kansas City Railway profile	681
From Lake Michigan by the Chicago and Northwestern Railway to Winona, and thence to St. Paul by leveling of United States Engineers (Gannett's Lists of Elevations, 1877, p. 3, corrected to accord with the height of Lake Michigan determined by the United States Lake Survey)	682·5

The mean of these twelve determinations is almost exactly 683 feet, as given by Major Allen; and the altitudes herein noted for St. Paul and Minneapolis and the railroads radiating from these cities are thereby referred to the sea level. The probable limit of error in the heights given by the Lake Survey for Lakes Michigan, Huron, and Superior, is only a fraction of a foot; and almost equal accuracy seems to be attained in this datum of reference at St. Paul.

Most of the railroad profiles here tabulated have been found, after reference to the common datum of the sea level, to agree exactly or within one or two feet at their points of intersection or junction with each other; and where so small adjustments were required, they have been made at these points without statement of them. Larger discrepancies are harmonized by locating their adjustment at one or more points which are definitely noted, with the amount of the corrections. Distribution of adjustments by gradual addition or subtraction along a considerable distance has been avoided, that the altitudes here published

may represent, as nearly as possible, the data of the original profiles. Whenever opportunities for better revision are afforded by additional surveys or by more definite and trustworthy means of comparison, these figures and adjustments may be further corrected with full knowledge of the original as well as the later surveys.

Exact or close agreements throughout nearly the entire extent of this complex network of railroads give good assurance of the correct reference of almost every portion to the sea level, with possible limits of error not exceeding a few feet. Thus the altitudes of Winnipeg, Portage la Prairie, Brandon, and the great lakes of Manitoba, of Regina and Medicine Hat in Assiniboia, of Calgary in Alberta, of Grand Forks, Devil's Lake, Minot, Buford, Fargo, Jamestown, and Bismarck, in North Dakota, of Aberdeen, Watertown, Sioux Falls, and Yankton, in South Dakota, and of Glendive, Livingston, Great Falls, and Helena, in Montana, appear to be determined with nearly as close accuracy as St. Paul and the Laurentian lakes.

The altitudes of every railroad in the basin of Lake Agassiz, and the heights of its beaches and deltas determined therefrom by continuous leveling along a thousand miles or more of its shore lines, seem to be correctly known throughout within less than five feet of possible error. This is especially important, as the beaches of Lake Agassiz are not now horizontal but have slight ascents northward, presenting very interesting problems for investigation, as to the amount of these changes in comparison with the sea level, when they were produced, and their causes.

This work will also be of value in studies of stratigraphic geology, and probably at some future time in determining the amount and rate of uplifts and depressions of the earth's crust; it will be the basis of reference in the preparation of contoured maps of this region; and it will be consulted by engineers in planning new railroad routes, improvements of the navigation of rivers, the utilization of water-power, and the construction of reservoirs and canals for irrigation.

Much space is accordingly given to the separate tabulation of the elevations of the principal rivers, so far as they are known from these railroad surveys and from other means of determination. In this connection the reports of the Mississippi and Missouri River Commissions afford valuable data of the lowest and highest stages of these rivers at various points where gauge records have been taken. The Commission reports refer these elevations either to zero of the several gauges (and these to the Cairo datum plane), as on the Mississippi, or to the St. Louis directrix, as on the Missouri; but in the tabulation of this bulletin they are referred to mean sea level, permitting more ready comparison of these records among themselves and with the other altitudes herein published.

The general index is arranged in three parts, giving references first for hills and mountains; second, for lakes; and third, for towns and

railroad stations. Each of these parts is further subdivided under the several states, and north of the international boundary under the several provinces of British America. The index notes the page or pages where the altitudes appear in the previous tabulation of the various railroad profiles and river systems, by reference to which their relations with other altitudes determined in their vicinity may be learned; but, after the page references, the index also gives the altitude of the hill, mountain, lake, town, or station cited, for the convenience of those who wish only the single altitude, without comparison with others or information as to the method of its determination.

Acknowledgments for assistance in this work are due, and are gratefully tendered, to Mr. Henry Gannett, of this Survey; to Prof. N. H. Winchell, State Geologist of Minnesota; to Mr. A. J. Hill, of St. Paul, who was the first to collect, more than twenty years ago, the principal part of the hypsometric data then determined by the early railroad surveys having offices in that city; to Major C. J. Allen, Major A. Mackenzie, and General O. M. Poe, of the United States Corps of Engineers; to S. D. Mason and Richard Relf, engineers of the Northern Pacific Railroad, by whom every facility has been courteously granted for the examination of their maps and profiles; to P. A. Peterson and R. M. Pratt, engineers of the Canadian Pacific Railway, for similar aid; likewise to George H. Webster, engineer of the Manitoba and Northwestern Railway; to N. D. Miller, engineer of the Great Northern (formerly the Saint Paul, Minneapolis and Manitoba) Railway, for opportunity to examine all the profiles of this great railway system; to George H. White, M. D. Rhame, and George B. Woodworth, of the Chicago, Milwaukee and St. Paul Railway; to the many other engineers, whose names appear in connection with the altitudes received from them, or copied by the author from profiles in their offices; to Collingwood Schreiber, in charge of Canadian Government railways; and to Dr. George M. Dawson and Dr. Robert Bell, of the Geological and Natural History Survey of Canada.

FLUCTUATIONS OF LAKE SUPERIOR, NOVEMBER, 1870, TO JANUARY, 1888.

Table showing in feet the mean elevation of Lake Superior above mean tide at New York, by months, from observations made above the locks at St. Mary's Falls canal, Mich., beginning November, 1870.

[From Gen. O. M. Poe, Lt. Col. of Engineers, U. S. Army, Detroit, Mich., February 14, 1888.]

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual means, Nov. 1 to Oct. 31.	Annual means, Jan. 1 to Dec. 31.
1870.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	601·84	601·61	.....	.....
1871.....	601·16	601·03	600·74	600·95	601·44	601·85	602.04	601·95	602·00	601·83	1·60	1·24	601·54	601·49
1872.....	0·97	0·86	0·66	0·58	1·47	1·60	1·97	2·36	2·43	2·30	2·17	1·75	1·50	1·59
1873.....	1·34	1·13	1·17	1·17	1·70	1·86	2 39	2·60	2·64	2·54	2·42	2·15	1·87	1·93
1874.....	1·50	1·34	1·21	1·11	1·60	1·93	2·33	2·36	2·35	2 48	2·37	2·12	1·90	1·89
1875.....	1·76	1·46	1·43	1·64	1·97	2·26	2·34	2·36	2·61	2·55	2·26	1·68	2·07⅛	2 03
1876 ...	1·66	1·60	1·43	1·38	1·77	2·74	3·16	3·20	3·22	2·90	2·62	2·13	2·25	2·32
1877.....	1·85	1·86	1·75	1·61	1·57	1·87	2·16	2·32	2·07	2·08	1·88	1·67	1·99	1 89
1878.....	1·47	1·20	1·13	1·12	1·13	1·62	1·73	1·68	1 44	1·54	1·42	1·23	1·47	1 39
1879.....	0·80	0·38	0·21	0·34	0·67	0·88	1·05	1·15	1·09	1·09	0·95	0·56	0 86	0·76
1880.....	0·36	0·28	0·19	0·23	0·92	1·73	1·96	1·84	1·09	1·75	1·79	1·54	1·06	1·21½
1881.....	1·19	1·10	1·12	1·04	1·44	1·65	1·87	1·77	1·95	2·44	2·30	1·95	1·57½	1 65
1882.....	1·47	1·27	1·17	1·13	1·52	1·62	1·96	2·05	1·97	1·90	1·84	1·55	1·69	1·62
1883.....	1·15	1·04	1·06	1·12	1·13	1·47	1·67	2·02	1·74	1·58	1·43	1·23	1·45	1·39
1884.....	1·11	1·08	0·96	0·68	1·15	1·14	1·38	1·42	1·48	1·57	1·62	1·43	1·22	1·25
1885.....	1·22	1·13	1·00	0·82	1·37	1·74	1·92	2·13	1·88	1·73	1·65	1·35	1·50	1·49½
1886.....	1·01	0·84	0·84	0·82	1·30	1·46	1·65	1·78	1·64	1·61	1·61	1·19	1·33	1·42
1887.....	0·95	0·84	0·77	0·64	1·01	1·44	1·78	1·70	1·56	1·73	1·50	1·10	1·27	1·25
1888....	0·95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sums.	21·92	18·44	16·84	16·38	23·16	28·86	33·36	34·69	34·09	33·62	33·27	27·51	26·55	26 58
Means	601·22	601·08	600·99	600·96	601·36	601·70	601·97	602·04	602 01	601·98	601·85	601·53	601. 56	601.56

Highest mean for 1 month, September, 1876	603·22
Lowest mean for 1 month, March, 1880	600·19
Range of mean elevation for 1 month during 17 years	3·03
Highest monthly mean, August	602·04
Lowest monthly mean, April	600·96
Range of monthly mean during 17 years	1·08
Highest annual mean, November 1, 1875, to October 31, 1876	602 25
Lowest annual mean, November 1, 1878, to October 31, 1879	600·86
Range of annual mean, November 1 to October 31, during 17 years	1·39
Highest annual mean, January 1 to December 31, 1876	602·32
Lowest annual mean, January 1 to December 31, 1879	600·76
Range of annual mean, January 1 to December 31, during 17 years	1·56

Mean elevation of surface of Lake Superior November 1, 1870, to January 31, 1888, 601.56 feet.

ALTITUDES OF RAILROADS.

NORTHERN PACIFIC RAILROAD SYSTEM.

MAIN LINE.

[From profile in the office of S. D. Mason, engineer, and Richard Relf, assistant engineer, St. Paul.]

The profile westward to the first crossing of Clark's Fork of the Columbia River is referred to sea level by calling Lake Superior 600 feet. A uniform addition of 2 feet is accordingly made here to the main line and its branches throughout this distance, as required by the United States Lake Survey. With this change a discrepancy of only 2 feet remains where this portion connects with the leveling from the Pacific Ocean, which gives elevations 2 feet higher than the leveling from Lake Superior.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Lake Superior, mean surface, from Jan. 1, 1871, to Dec. 31, 1875 (Report of United States Lake Survey)	0·0	601·78
Same, from Nov. 1, 1870, to Jan. 31, 1888, according to United States engineer's gauge, Sault Ste. Marie	0·0	601·56
Duluth, freight depot and elevators (three-fourths mile east from the passenger depot)	0·0	607
Duluth, passenger depot	0·0	607
Oneota	3·8	631
Summit level	4·7–5·4	637
Oneota Junction, St. Paul and Duluth Short Line	5·9	629
Spirit Lake Station	7·8	610
Fond du Lac	13·5	607
Mason Creek, water, 607; grade	14·0	622
Little River, bed, 662; grade	16·4	733
Conglomerate Creek, bed, 696; grade	17·4	789
Greeley	18·2	838
Thomson	21·7	1032
St. Louis River, Dalles bridge, bed, 992; low and high water, 997–1,020; grade	22·0	1044
Northern Pacific Junction, St. Paul and Duluth Railroad. (This railroad from Duluth to the Northern Pacific junction is owned jointly by the St. Paul and Duluth and Northern Pacific Railroad Companies.)	23·0	1083
Otter Creek, bed	26·4	1128
Pine Grove	28·3	1237
Sawyer (formerly Norman)	33·5	1317
Corona	39·0	1303
Kettle River, bed	41·1	1287
Summit, natural surface	44·0	1331
Cromwell (at Island Lake)	45·0	1306
Tamarack River, bed, 1,287; grade	50·7	1301
Wright	51·0	1309
Tamarack (Sicottes) Station	57·1	1271
Hay River, bed, 1,228; grade	61·2	1238
Summit, natural surface	61·8	1244
Hay River, second crossing, bed, 1,222; grade	63·0	1232
Sandy River, bed, 1,219; grade	64·3	1228
McGregor	66·0	1228
Portage Lake, grade	71·3	1220
Summit, natural surface	72·8	1266
Kimberly	75·0	1237
Rice River, bed, 1,209; water, 1,213; grade	75·5	1226

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Summit, natural surface	79·8	1254
Rossburg	80·9	1222
Sisabagama Creek, bed, 1,206; grade	82·5	1214
Summit, natural surface	84·3	1241
Mud River, bed, 1,191; grade	86·7	1205
Aitkin	86·8	1208
Outlet of Pickerel Lake, bed, 1,208; grade	88·6	1215
Summit, natural surface	89·2	1224
Cedar River, bed, 1,199; grade	90·8	1212
Cedar Lake Station	92·0	1222
Summit, natural surface, 1,306; grade	96·5	1298
Deerwood	97·3	1277
Swamp, grade	99·0	1268
Summit, natural surface, 1,308; grade	102·6	1290
Jonesville	106·8	1238
Brainerd, junction of St. Paul and Northern Pacific Railroad	113·9	1207
Brainerd Station, 138 miles from St. Paul	114·0	1209
Mississippi River, bed, 1,144; extreme low water (1874), 1,150; extreme high water (1866), 1,167; grade	114·5	1211
Depression, grade	115·1	1196
Baxter	118 0	1205
Summit, natural surface	119·9	1212
Gull River, bed, 1,165; water, 1,170; grade	121·5	1191
Gull River Station	121·8	1191
Summit, natural surface	123·7	1210
Sylvan Lake Station	124·0	1207
Pillager Creek, bed, 1,172; water, 1,175; grade	126·8	1195
Pillager	127·5	1203
Wheelock (formerly Bath)	132·5	1214
Crow Wing River, bed, 1,205; water, low stage, 1,208; grade	135·5	1225
Motley	136·0	1227
Hayden, at a summit of grade, natural surface, 1,257; grade	140·4	1255
Hayden Brook, bed, 1,230; grade	142·5	1243
Staples' Mills, junction of new line of St. Paul and Northern Pacific Railroad, 141·6 miles from St. Paul	143·8	1274
Dower Lake Station (a summit of grade)	145·8	1293
Summit, natural surface	150·1	1344
Aldrich	150·5	1327
Partridge River, bed, 1,306; water, 1,307; grade	150·7	1325
Verndale	154·5	1349
Wing River, bed, 1,314; grade	155·7	1330
Summit, natural surface	157·4	1359
East branch of Union Creek, bed, 1,328; grade	160·1	1343
West branch of Union Creek, bed, 1,323; grade	160·5	1343
Wadena	161·0	1350
Wadena Junction, Northern Pacific, Fergus Falls and Black Hills Railroad	162·9	1352
Summit, natural surface	163·2	1356
Oak Creek, bed, 1,310; grade	164·7	1326
Leaf River, bed, 1,303; water, 1,305; grade	165·5	1315
Bluffton	166·0	1323
Bluff Creek, bed, 1,308; grade	166·1	1329
Little Run, bed, 1,328; grade	167·0	1341
Amboy	169·3	1378
New York Mills	174·0	1410
Summit, natural surface, highest on this railroad in Minnesota	176·4	1433
Richland	179·0	1396
Otter Tail River, bed, 1,324; water, 1,327; grade	182·7	1343
Perham	184·8	1370

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Luce	190·0	1373
Otter Tail River, second crossing, bed, 1,340; grade	191·9	1361
Thompson's Lake, grade	193·4	1372
Hobart	194·6	1386
Summit, natural surface	195·3	1404
Otter Tail River, third crossing, bed, 1,358; grade	195·4	1385
Frazee	196·0	1389
Summit, natural surface	200·7	1422
Johnson	201·0	1394
Depression at Detroit Lake, grade	204·1	1347
Pelican River, bed, 1,339; grade	205·2	1352
Detroit	206·0	1364
Summit, natural surface, 1,397; grade	208·0	1390
Cut, 31 feet deep, grade	210·1	1377
Audubon	213·0	1310
Creek, bed, 1,270; grade	214·1	1295
Summit, natural surface	216·4	1350
Lake Park	218·5	1336
Hay Creek, bed, 1,253; grade	220·4	1286
Hay Creek, bed, 1,202; grade	223·6	1207
Hillsdale	224·0	1197
Hay Creek, bed, 1,167; grade	225·9	1180
Winnipeg Junction, Duluth and Manitoba Railroad	226·6	1181
Buffalo River, bed, 1,150; grade	226·8	1166
Same, second crossing, bed, 1,143; grade	227·5	1157
Same, third crossing, bed, 1,140; grade	228·1	1152
Same, fourth crossing, bed, 1,133; grade	229·3	1143
Same, fifth crossing, bed, 1,131; grade	229·6	1146
Hawley	230·0	1151
Summit, natural surface, 1,198; grade	231·0	1193
Upper or Herman Beach of Lake Agassiz, natural surface at crest of beach ridge, 1,114; natural surface 12 to 125 rods east of crest of beach ridge, 1,097 to 1,100; base of beach ridge, 25 rods west from crest, 1,099; grade of railroad at intersection of the beach ridge	233·7	1100
Muskoda	234·0	1090
Campbell Beach of Lake Agassiz, 30 rods wide, crest, 1,004, with descent of 4 feet east and 11 feet west; grade	237·1	998
Second Campbell Beach, about 50 rods wide, crest, 1,000, with descent of 7 feet east and 19 feet west; grade	237·4	988
McCauleyville Beach, about 20 rods wide, crest, 983, with descent of 3 feet east and 10 feet west; grade	237·6	979
Buffalo River, bed, 940; grade	238·4	957
(There is no ascent west of this river, the grade all the way to Glyndon being lower than on the bridge.)		
Stockwood	238·6	948
Glyndon	242·8	925
South branch of Buffalo River, bed, 896; grade	244·9	917
Tenny	245·3	922
Dilworth	248·2	909
Moorhead	251·5	905
Red River of the North, bed, 862; extreme low water, 866; extreme high water (1882), 898; ordinary low and high water, 870–885 or 890; grade	252·0	905
Fargo	252·5	905
(Thence a level grade, 905 or in part 904½, extends west 12 miles.)		
Junction, Fargo and Southwestern Railroad	253·7	905
Haggart	257·0	905
Sheyenne River, bed, 881; grade	258·2	905
Canfield	261·0	905
Mapeton	265·0	907

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Maple River, bed, 886; water, 888; grade	265·3	908
Beach ridge of Lake Agassiz, 10 feet high and 60 rods wide (including the slopes), crest, 919; grade of railroad	267·4	916
Greene	267·5	916
Dalrymple	270·5	922
Casselton	272·8	934
Goose Creek, bed, 928; grade	272·9	935
Crossing the St. Paul, Minneapolis and Manitoba Railway, line from Everest to Mayville	273·2	938
Sidney, at crossing of the St. Paul, Minneapolis and Manitoba Railway, line from Everest to Hope	276·3	954
Campbell Beach of Lake Agassiz, crest, 994; grade	279·1	987
(This beach ridge is 60 rods wide (including the slopes), and rises 15 feet above the nearly level expanse thence eastward. Its crest is 10 feet above the hollow, 40 rods wide, on its west side.)		
Wheatland	279·3	993
Big Cooley, bed, 1,057; grade	283·2	1076
Magnolia	283·4	1077
Upper or Herman Beach of Lake Agassiz, crest, 1,101; grade	283·9	1092
(This beach ridge is about 40 rods wide. Its crest is 20 feet above the nearly level land on the east and 7 feet above the depression on its west side. The ascent thence westward rises to 1,101 feet in a third of a mile.)		
Summit, natural surface and grade	288·5	1208
Buffalo	288·8	1202
Maple River, water, 1,130; grade	291 6	1140
Tower City	294·8	1172
Oriska	300·3	1270
Summit, natural surface, 1,442; grade	304·5	1438
Alta	305·3	1427
Sheyenne River, bed, 1,200; grade	310·0	1230
Valley City	310·5	1220
Hobart	318·3	1419
Sanborn, junction of Sanborn, Cooperstown and Turtle Mountain Railroad	322·0	1444
Beside Lake Eckelson, natural surface marshy, 1401–1402; grade	324·5–324·9	1417
(On the west side of Lake Eckelson a steep bluff rises 40 feet to 1,442; on the east a gradual ascent rises to 1,432.)		
Eckelson	325·5	1445
Urbana	330·8	1472
Spiritwood	334·8	1479
Spiritwood Cooley (or Seven-Mile Creek), bed, 1,403; grade	337·4	1414
Bloom	339·8	1486
Summit, natural surface and grade	342·5	1495
Jamestown, junction of the James River Valley Railroad	345·5	1408
James River, bed, 1,382; grade	345·7	1397
Junction of the Jamestown and Northern Railroad	346·5	1399
Eldridge	352·5	1541
Windsor	362·0	1840
Cleveland	365·8	1842
Medina	374·5	1794
Crystal Springs	382·5	1792
Tappen	390·8	1762
Long Slough, bottom, 1,734; grade	392·7	1738
Dawson	396·0	1748
Steele	404·0	1859

NORTHERN PACIFIC RAILROAD SYSTEM.—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Geneva	410·8	1835
Driscoll	415·0	1871
Sterling	422·5	1867
Summit of the Coteau du Missouri, here inconspicuous, average of natural surface, 1,900; highest grade	423·8	1882
McKenzie	428·8	1698
Menoken	434·0	1720
Apple Creek Station	443·0	1644
Apple Creek, water	443·0	1626
Bismarck	447·0	1670
Missouri River, low water, 1,618; highest water in ordinary years, 1,638; same, in spring of 1881 and 1887, 1,646; grade	449·2	1692
Bluff close east of this bridge		1747
Bottom land of Missouri River	449·5–451·5	1632–1637
Mandan	452·2	1646
Heart River:		
First crossing, water, 1,634; grade	453·1	1649
Second crossing, water, 1,635; grade	453·8	1648
Third crossing, water, 1,638; grade	454·9	1655
Sunnyside	455·2	1658
Heart River:		
Fourth crossing, water, 1,643; grade	456·2	1660
Fifth crossing, water, 1,645; grade	456·7	1659
Sixth crossing, water, 1,646; grade	457·6	1662
Cut, 40 feet deep; grade	459·9	1728
Marmot	460·7	1731
Sweet Brier Creek:		
First crossing, water, 1,679; grade	462·4	1695
Second crossing, water, 1,686; grade	463·0	1703
Third crossing, water, 1,691; grade	463·4	1707
Sweet Brier Station	468·0	1806
Sweet Brier Creek, one of many crossings of this stream, this being "where the main Sweet Brier comes in from the north," water, 1,848; grade	471·5	1871
Sedalia	476·3	2032
Summit between the Sweet Brier and the Blue Grass Valleys, natural surface and grade the same	479·7	2164
New Salem	479·9	2163
Blue Grass Station	483·5	2041
Cold Spring tank	486·1	1984
Sims Station, siding at Bly's coal mine	487·3	1962
Summit between Hailstorm and Curlew Creeks, cutting 30 feet; grade	491·3	1916
Almont	492·5	1920
Curlew Creek, first crossing, water, 1,912; grade	494·5	1934
Curlew siding	497·7	1956
Kurtz	504·6	2025
Glenullen	509·7	2070
Eagle's Nest siding	515·0	2098
Summit between Curlew Creek and Big Knife River, natural surface and grade the same	519·5	2151
Big Knife River, first crossing, water, 2,134; grade	521·4	2148
Hebron	522·1	2158
Knife River siding	523·7	2188
Antelope siding	531·4	2411
Summit opposite to Young Man's Butte, cutting 4 feet; grade	533·2	2458
Richardton	537·1	2466
Taylor	542·6	2488
Crossing of Fort Keogh stage road; grade	547·3	2417
Gladstone	550·3	2348
Green River, low and high water, 2,277–2,291; grade	551·1	2313

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles	*Feet.*
Upper Heart River, first crossing, low and high water, 2,285–2,300; grade	553·0	2308
Grade at "16-ft. vein of good coal."	557·2	2352
Dickinson	561·6	2405
Eland	565·6	2436
South Heart siding	573·1	2482
Belfield	581·9	2579
Fryburg Spur	587·5	2768
Summit between Heart River and the Little Missouri River, cutting 16 feet; grade	588·1	2786
(Thence westward the profile is very irregular, crossing the "Bad Lands," with frequent cuts and fills of 20 to 50 feet.)		
Sully Springs	593·0	2575
Summit between Sully and Poland Creeks, cutting 29 feet; grade	595·8	2514
Scoria	596·6	2482
Medora	601·1	2267
Little Missouri River, bed, 2,244; high water, 2,259; grade	601·5	2271
Little Missouri Station	601·7	2266
Andrews	609·6	2478
Sentinel Butte siding	617·8	2709
Summit between Andrews and Beaver Creeks, cutting 8 feet; grade	620·8	2807
Beach	626·1	2756
Line between North Dakota and Montana	628·2	2811
McClellan	635·0	2687
Mingusville	637·0	2652
Beaver Creek here, bed, 2,630; high water, 2,640.		
Summit between Beaver and Glendive Creeks, natural surface and grade the same	640·3	2837
Beaver Hill Station	641·0	2757
Hodges	647·4	2508
Allard	657·4	2216
Glendive Creek, lowest crossing, bed, 2,049; grade	664·4	2076
Glendive	667·6	2069
Yellowstone River here, ordinary low water about 2,045.		
Milton	682·2	2116
Fallon	697·0	2208
O'Fallon Creek, low water	697·0	2147
Terry	706·8	2242
Powder River, low water	716·0	2201
Blatchford	716·9	2247
Ainslie	726·8	2274
Dixon	737·2	2322
Miles City	746·0	2355
Tongue River, low water	747·0	2345
Fort Keogh	748·4	2367
Horton	757·7	2395
Hathaway	766·6	2428
Rosebud	777·8	2462
Forsythe	791·2	2514
Howard	801·6	2561
Sanders	812·0	2595
Myers	823·2	2659
Big Horn	833·6	2690
Big Horn tunnel, grade	837·4	2737
Custer	839·5	2727
Riverside	848·1	2779
Bull Mountain Station	856·1	2842
Pompey's Pillar	863.8	2871

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Clermont	871·8	2950
Huntley	880·1	3014
Yellowstone River, first crossing, low water	891·0	3079
Billings	892·7	3117
Laurel	906·0	3255
Park City	915·7	3387
Rapids	928·7	3517
Stillwater	933·1	3572
Merrill	941·6	3657
Reedpoint	941·1	3687
Yellowstone River, second crossing, low water	944·7	3676
Greycliff	960·1	3847
Big Timber	973·9	4072
Springdale	987·7	4190
Elton	995·3	4282
Mission	999·7	4345
Yellowstone River, third crossing, low water	1007·0	4437
Livingston, junction with Rocky Mountain Railroad of Montana (to Yellowstone National Park)	1008·2	4487
Coal Spur	1012·9	4737
Muir	1020·2	5502
Big Belt Mountains, range summit	1021·1	5537
Same, tunnel, summit grade	1021·1	5567
Gordon	1028·4	4907
Bozeman	1033·0	4754
Belgrade	1042·9	4437
Hamilton, about	1050·0	4242
Moreland	1052·1	4220
Gallatin River, low water, about	1056·0	4077
Gallatin	1061·5	4032
Magpie	1072·0	3981
Painted Rock	1079·2	3955
Toston	1088·6	3915
Townsend	1097·9	3811
Missouri River, low water	1099·0	3793
Bedford	1101·0	3784
Placer	1113·0	4292
Spokane summit, grade	1115·6	4347
Clasoil	1120·2	4125
Prickly Pear Junction, with Helena and Jefferson County Railroad	1126·3	3889
Prickly Pear Creek, low water	1128·0	3867
Helena	1131·2	3932
Red Mountain Junction, Helena and Red Mountain Railroad	1133·1	3909
Ten-Mile Creek, low water	1135·0	3877
Birdseye	1138·9	4210
Clough Junction, Helena and Northern Railroad	1140 6	4315
Butler	1144·2	4727
Mullan tunnel, summit grade	1151·7	5550
Rocky Mountains, summit of Mullan Pass	1151·7	5575
Mullan	1152·1	5532
Elliston	1160·3	5038
Avon	1169·0	4677
Garrison, junction of Montana Union Railway	1182·0	4317
Butte City (Montana Union Railway)	1233·0	5703
Lloyd	1183·3	4297
Gold Creek, low water	1189·7	4205
Gold Creek Station	1190·6	4255
Drummond, junction with Drummond and Phillipsburg Railroad	1202·7	3945
Bearmouth	1215·1	3789
Carlan	1222·7	3684

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Hellgate River, low water, 3,631; grade	1226·4	3646
Bonita	1230·7	3566
Wallace	1238·5	3450
Bonner	1248·5	3297
Big Blackfoot River, low water, 3,223; grade	1249·0	3277
Missoula River, first crossing, low water, 3,206; grade	1250·5	3251
Same, second crossing, low water, 3,191; grade	1251·8	3231
Missoula, junction with Missoula and Bitter Root Valley Railroad	1255·5	3197
De Smet	1261·9	3215
Evaro (summit of Coriacan Defile Pass, grade)	1272·1	3948
Arlee	1283·0	3059
Jocko River, low water, 2,954; grade	1284·5	2999
Ravalli	1292·5	2692
Jocko	1299·5	2509
Duncan	1306·5	2499
Perma	1314·5	2495
Clark's Fork of Columbia River, first crossing, low water. (NOTE.—From here west the altitudes are from mean tide, Pacific Ocean, and are 2 feet *above* those coming from the east.)	1317·2	2464
Horse Plains	1333·0	2463
Eddy	1347·5	2415
Clark's Fork, second crossing, low water	1362·5	2298
Belknap	1363·5	2405
Trout Creek Station	1380·5	2375
Noxon	1395·0	2186
Heron	1405·0	2261
Cabinet	1411·0	2187
Clark's Fork, third crossing, low water	1416·8	2065
Clark's Fork Station	1418·5	2086
Hope	1428·5	2 08
Mouth of Pack River, ordinary stage of water of Lake Pend d'Oreille	1433·0	2062
Lake Pend d'Oreille, lowest stage	1418–1444·0	2059
Sand Point	1443·5	2100
Algoma	1449·5	2214
Granite	1466·7	2290
Athol	1471·5	2210
Chilco	1475·1	2450
Idaho Line	1495·0	2124
Trent	1503·9	1989
Spokane River, low water	1504·0	1925
Spokane Falls	1513·1	1910
Haugman's Creek, low water	1515·9	1793
Marshall Junction, with Spokane and Palouse Railway	1521·8	2134
Stevens	1539·8	2282
Sprague	1553·8	1908
Harriston	1563·7	1950
Ritzville	1577·5	1825
Lind	1594·8	1363
Palouse Junction, with Columbia and Palouse Railroad	1622·6	858
Eltopia	1641·1	600
Pasco Junction, Cascade division	1658·0	385
Ainsworth	1660·8	351
Snake River, ordinary low water	1661·0	328
Wallula Junction, with Walla Walla and Dayton Line, Oregon Railway and Navigation Co	1674·5	326
Walla Walla	1706·0	925
Juniper	1687·0	318
Umatilla Junction, with Pendleton and Baker City line, Oregon Railway and Navigation Co	1702·0	302
Umatilla River, low water	1702·3	270

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

MAIN LINE—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Coyote	1718·0	257
Willows	1738·0	234
Alkali	1747·0	232
Quinn's	1762·0	236
Grant's	1778·0	180
Des Chutes River, low water	1785·0	170
Celilo	1787·0	160
The Dalles	1800·0	106
Mosier	1816·0	100
Hood River, low water	1823·0	80
Viento	1831·0	104
Bonneville	1847·0	60
Bridal Veil	1860·0	46
Sandy River, low water	1871·0	30
Troutdale	1871·0	60
Clarnie	1879·0	214
Portland	1889·0	30
Columbia City	1920·0	90
Columbia River, high tide	1928–1929·0	17
Kalama	1929·2	33
Castle Rock	1950·0	83
Winlock	1965·8	328
Newaukum River, low water	1977·0	192
Chehalis	1979·3	204
Centralia	1983·2	207
Tenino, junction with Olympia and Chehalis Valley Railroad	1995·0	315
Des Chutes River, low water	2001·0	325
Yelm Prairie	2008·6	387
Nisqually River, low water	2010·6	265
Lakeview	2025·3	324
Tacoma	2034·2	31

CASCADE DIVISION.

[From profile in the office of S. D. Mason, engineer, and Richard Relf, assistant engineer, St. Paul.]

The profile is referred to a datum plane 5·72 feet below mean sea level (as determined by the U. S. Coast Survey) in Commencement Bay, Tacoma; and therefore its altitudes have received in the following tabulation a uniform subtraction of 6 feet. With this change, the height of Pasco Junction is 1 foot above that determined in the survey of the main line.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Pasco Junction	1658·0	386
Columbia River, low water (1887), 320; high water (1876), 348; grade on bridge	1659·1 to 1659·6	364
Kennewick	1661·0	350
Relief	1666·9	565
Badger (a summit of grade)	1675·6	687
Horseshoe Bend of Yakima River, water, 488; grade	1682·2	522
Kiona	1685·1	499
Bender	1692·9	639
Yakima River, water at ordinary low stage, ¼ mile east of Bender	1692·4	544
Same, 1 mile west of Bender	1693·9	572
Prosser	1698·8	668
Mabton	1710·8	722

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

CASCADE DIVISION—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Satus	1718·8	680
Toppenish Creek, bed, 704; grade	1723·1	718
Toppenish	1729·3	763
Simcoe	1736·5	863
Yakima	1748·3	1069
Natches River, low and high water, 1,080–1,086; grade	1750·0	1100
Yakima River, first crossing, low and high water, 1,120–1,127; grade	1754·4	1149
Selah	1755·5	1151
Yakima River, second crossing (at lower end of Big Cañon), bed, 1,189; water, 1,196; grade	1760·9	1225
Roza	1764·2	1251
Gibraltar Rock, cutting 57 feet; grade	1771·7	1336
Umtanum Creek, bed, 1,321; grade	1772·1	1340
Umtanum	1772·8	1351
Yakima River, third crossing (at upper end of Big Cañon), low and high water, 1,403–1,413; grade	1779·2	1426
Wilson Creek, bed, 1,410; high water, 1,418; grade	1779·4	1426
Thrall	1780·4	1437
Ellensburg	1785·3	1513
Yakima River, fourth crossing, bed, 1,605; grade	1791·5	1629
Thorp	1794·0	1664
Yakima River, fifth crossing, bed, 1,673; grade	1796·3	1698
Cañon (near the upper cañon of the Yakima)	1801·8	1790
Teanaway River, bed, 1,811; grade	1804·9	1828
Teanaway	1805·7	1839
Clealum	1809·8	1912
Clealum River, bed, 1,961; grade	1813·8	1986
Yakima River, sixth crossing, bed, 2,000; grade	1815·8	2025
Nelson's	1816·3	2032
Big Creek, bed, 2,088; grade	1820·2	2104
Easton	1823·2	2171
Tunnel, natural surface, 2,314; grade	1825·8	2234
Cabin Creek, bed, 2,217; grade	1826·0	2237
Martin	1830·8	2777
Stampede tunnel, east end, grade	1831·6	2839
Same, summit of grade	1832·5	2849
Same, west end, grade	1833·4	2812
Stampede pass, crossing the Cascade range	1832·5	3980
Stampede, engine house	1833·9	2746
Cole	1838·4	2164
Weston	1841·4	1854
(Level grade 1,500 feet each side of Weston.)		
Green River at bend of loop of railroad 1 mile southeast of Weston, bed, 1,793; grade	1842·5	1809
Green River, bed, 1,568; grade	1847·2	1584
Hot Springs	1848·2	1544
Maywood (level grade here for 1,700 feet)	1853·1	1345
Eagle Gorge	1861·1	1088
Green River:		
Low and high water, 1,048–1,056; grade	1861·4	1074
Low and high water, 1,004–1,009; grade	1862·3	1039
At eastern one of three bridges near together, low and high water, 895–904; grade	1865·3	925
At western one of these bridges, low and high water, 875–885; grade	1865·6	917
Low and high water, 823–833; grade	1867·4	846
Lowest crossing, low and high water, 809–819; grade	1867·6	846
Palmer	1868·7	874
Enumclaw	1877·6	734
Boise Creek Station	1879·8	685
White River, bed, 615; grade	1880·0	685

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

CASCADE DIVISION—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Buckley	1881·0	716
Cascade	1885·2	473
South Prairie	1886·0	423
White River, low and high water, 142–146; grade	1893·1	165
Stuck Junction	1894·4	100
Stuck River, low and high water, 83–90; grade	1895·0	101
Alderton	1898·9	65
Puyallup River, low and high water, 48–60; grade	1900·2	72
Meeker	1901·4	62
Puyallup	1902·7	45
Clark's Creek, bed, 8; water, 12; grade	1905·1	30
Reservation	1909·1	12
Commencement Bay, depth of water at mean sea level, 10 feet; grade	1910·8 to 1911·2	9
Tacoma, top of wharf	1911·7	10

Lowest tide observed at Tacoma by U. S. Coast Survey, 1877, 10.5 feet below mean sea level.

Highest tide observed by Coast Survey, 1877, 5 feet above mean sea level.

Highest tide observed by D. D. Clark, 1884, 7 feet above mean sea level.

Extreme range between low and high tide, 17·5 feet.

ST. PAUL AND NORTHERN PACIFIC RAILROAD.

(Operated by the Northern Pacific Railroad Company.)

MAIN LINE, ST. PAUL TO BRAINERD.

[From profile in the office of J. W. Kendrick, engineer, St. Paul.]

This profile has a discrepancy of 4½ feet at Little Falls, north of which place its figures are copied with a uniform addition of 1 foot, which makes them agree exactly with the corrected elevations of the Northern Pacific Railroad at Brainerd. From St. Paul to Little Falls it requires a uniform subtraction of 4½ feet, which is here made, giving agreement with connecting railways at St. Paul, Minneapolis, and St. Cloud.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, union depot	0·0	703
Mississippi street, grade	1·6	784
Como avenue, grade	4·6	911
Warrendale	5·3	925
Summit, cutting 2 feet; grade	5·6	933
Snelling avenue (Hamline)	6·2	922
St. Anthony Park Station (a summit of grade)	8·0	904
University avenue, Minneapolis	9·4	827
Mississippi River, at bridge of this railroad near the State University, bed, 716; low water, 720; top of St. Peter sandstone in both bluffs, 759; top of Trenton limestone in east bluff, 789, and in west bluff, 784; grade	10·0	815
Minneapolis, St. Paul, Minneapolis and Manitoba (union) depot; grade (3 feet above that of St. Paul, Minneapolis and Manitoba Railway)	11·4	813
Mississippi River at bridge of this railroad in the north part of Minneapolis, bed, 783; low and high water, 794–803; grade	13·2	825
Fridley	17·4	847
Summit, grade	17·8	854

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

ST. PAUL AND NORTHERN PACIFIC RAILROAD—Continued.

MAIN LINE, ST. PAUL TO BRAINERD—continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Rice Creek, mill pond, bed, 812; water, 818; grade	18·9	845
Summit, grade	22·4	881
Coon Creek, bed, 824; water, 826; grade	23·4	858
Coon Creek Station	25·0	867
Anoka	28·5	878
Rum River, bed, 828; low and high water, 840–847; grade	29·2	863
Itasca	35·6	885
Elk River Station	40·5	893
Elk River, bed, 886; water, 893; grade	45·5	909
Bailey's	46·1	913
Big Lake Station	49·4	935
Becker	57·5	972
Clear Lake Station	64·3	991
Cable	70·4	1012
East St. Cloud	75·5	1025
Crossing St. Cloud and Hinckley branch, St. Paul, Minneapolis and Manitoba Railway	75·8	1025
Sauk Rapids	77·3	1005
Mississippi River at the mouth of Sauk River	77·3	988
Summit, grade	82·6	1058
Watab	83·0	1053
Goodhue brook, grade on bridge	85·1	1048
Little Rock River, water, 1,007; grade	86·3	1025
Rice's	90·2	1062
Platte River, water, 1,059; grade	95·9	1073
Royalton	96·8	1080
Gregory	102·6	1100
Little Falls, junction of Little Falls and Dakota Railroad	107·6	1117
Belle Prairie	111·9	1132
Topeka	115·3	1143
Summit, grade	120·0	1175
Fort Ripley	120·9	1169
Nokasippi River, bed, 1,134; low water, 1,139; grade	121·9	1154
Lenox	126·3	1176
Crow Wing	130·2	1194
Buffalo Creek, bed, 1,173; water, 1,175; grade	134·0	1206
Summit, cutting 6 feet; grade	135·0	1234
Buckhorn Creek, bed, 1,190; water, 1,192; grade	136·5	1215
Brainerd, junction with Northern Pacific Railroad	137·9	1207
Brainerd Station	138·0	1209

LITTLE FALLS TO STAPLES' MILLS.

[From profile in the office of S. D. Mason, engineer, St. Paul.]

Agreement is exact with the corrected main lines at Little Falls and Staples' Mills.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Little Falls, main line	107·6	1117
Junction with Little Falls and Dakota Railroad close west of the Mississippi Bridge	108·3	1112
Darling	112·3	1154
South fork of Little Elk River, water, 1,160; grade	117·7	1174
Randall	118·1	1178
Relf	123·3	1265
Summit, cutting 18 feet; grade	126·1	1333

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

ST. PAUL AND NORTHERN PACIFIC RAILROAD—Continued.

LITTLE FALLS TO STAPLES' MILLS—continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Depression at Fish Trap Lake, filling 11 feet; grade	128·1	1286
Fish Trap Lake, about 1,273; Lake Alexander, about 1,275.		
Lincoln	129·4	1281
Fish Trap Creek, bed, 1,252; grade	131·4	1269
Summit, cutting 26 feet; grade	133·3	1276
Fish Trap Creek, bed, 1,237; grade	135·3	1248
Birdsall	135·6	1245
Long Prairie River, bed, 1,223; water, 1,227; grade	135·9	1243
Hayden Creek, bed, 1,234; grade	140·5	1247
Staples' Mills, junction with Northern Pacific Railroad, 143·8 miles from Duluth	141·6	1274

LITTLE FALLS AND DAKOTA RAILROAD.

[Operated by Northern Pacific Railroad Company. From profile in the office of S. D. Mason, engineer, St. Paul.]

With changes here made as required by this profile to refer it to sea level at Little Falls and to join its three distinct series of leveling, it agrees with the connecting railways at Sauk Center, Glenwood, and Morris

	From Little Falls.	Above the sea.
	Miles.	*Feet.*
Little Falls, junction with St. Paul and Northern Pacific Railroad, 107·6 miles from St. Paul	0·0	1117
Mississippi River, bed, 1,086; low water, formerly, 1,090; water now raised by dam to 1,099; grade	0·5	1112
Pike Creek, bed, 1,106; grade	3·8	1118
Summit, cutting 4 feet; grade	6·8	1198
La Fond	7·2	1186
Summit, cutting 2 feet; grade	9·2	1213
Summit, cutting 1 foot; grade	10·5	1214
Milkie's Creek, bed, 1,174; grade	11·0	1185
Baiu's Run, bed, 1,157; grade,	13·1	1166
Irish Creek, bed, 1,154; grade	13·7	1161
Swan River, bed, 1,151; low water, 1,154; grade	14·3	1164
Swanville	16·1	1173
Summit, cutting 6 feet; grade	17·0	1194
Manley Creek, bed, 1,171; water, 1,173; grade	18·0	1179
Summit, cutting 23 feet; grade	19·2	1261
Hansen	20·6	1270
Summit, natural surface and grade the same	20·8	1271
Cogel (summit, natural surface and grade the same)	22·6	1294
Gray Eagle	25·1	1225
Prairie Brook, bed, 1,179; grade	27·8	1194
Birch Bark Lakes, water, about	27·8	1177
Brook, bed, 1,201; grade	28·4	1221
Birch Lake Station	28·6	1229
Summit, natural surface and grade	29·7	1283
Spaulding	31·1	1294
Summit, cutting 13 feet; grade	32·6	1340
Sauk River, bed, 1,214; low water, 1,221; grade	36·7	1227
Sauk Center	37·6	1244
Same, crossing St. Paul, Minneapolis and Manitoba Ry	37·8	1255
Westport	47·8	1334
Ashley Creek, a half mile below Westport Lake, bed, 1,319; grade	48·7	1331

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

LITTLE FALLS AND DAKOTA RAILROAD—Continued.

	From Little Falls.	Above the sea.
	Miles.	*Feet.*
Villard	52·7	1360
Lakes Villard and Amelia, water	54·2	1347
Summit at crossing of the Minneapolis and Pacific Railway, natural surface and grade	59·2	1415
Glenwood	59.6	1403
Rue's Run, bed, 1,262; grade	61.7	1299
Trapper's Run, near Pelican Lake, bed, 1,145; grade	64·2	1171
Lake Whipple (formerly called White Bear Lake and recently Lake Minnewaska), low and high water	67·1	1133–1137
Water tank, grade	68·3	1159
Starbuck	68·5	1161
Little Chippewa River, bed, 1,149; grade	72·7	1157
Summit, cutting 4 feet; grade	74·6	1185
Chippewa River, bed, 1,110; grade	78·3	1124
Cyrus	78·7	1142
Summit, cutting 1 foot; grade	82·4	1191
Pomme de Terre River, bed, 1,074; grade	86·0	1087
Morris	87·9	1129

NORTHERN PACIFIC, FERGUS AND BLACK HILLS RAILROAD.

[Operated by Northern Pacific Railroad Company. From profile in the office of S. D. Mason, engineer, St. Paul.]

The elevations given by the profile receive here a uniform addition of 2 feet, like the Northern Pacific Railroad. Intersecting railways at Fergus Falls, Breckenridge, and Wahpeton show exact agreement.

	From Wadena.	Above the sea.
	Miles.	*Feet.*
Wadena Junction, Northern Pacific Railroad, 162·9 miles from Duluth	1·9	1352
Oak Creek, bed, 1,336; grade	3·3	1349
Bluff Creek, bed, 1,325; grade	5·4	1355
Deer Creek, bed, 1,3[illegible]0; grade	10·0	1391
Deer Creek Station	10·3	1396
Summit, cutting 5 feet; grade	12·3	1421
Rock Creek, bed, 1,395; grade	12·7	1411
Summit, grade	13·1	1426
Parkton	13·9	1396
Willow Creek, bed, 1,408; grade	17·4	1422
Henning	18·0	1439
Pease Prairie, general surface	19–21	1452
East Battle Creek, bed, 1,371; grade	23·6	1382
Vining	24.1	1391
Clitherall	29·1	1346
Summit, grade	29·7	1370
Outlet of Lake Clitherall, bed, 1,333; grade	31·3	1342
Lake Clitherall, water	29–31	1334
Battle Lake Station	33·3	1356
Outlet of Turtle Lake, bed, 1,329; grade	36·7	1341
Turtle Lake, low and high water	36·7	1325–1330
Maplewood (station discontinued)	38·9	1362
Underwood	41·3	1345
Outlet of Bass Lake, bed, 1,329; grade	42·1	1337
Bass Lake, low and high water	42·1	1327–1330
Wall Lake Station	45·8	1292
Red River, bed, 1,230; water, 1,233; grade	46·9	1248
Mill Park	49·1	1225
Red River, bed, 1,193; grade	50·1	1206
Pelican Junction	51·0	1189

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

NORTHERN PACIFIC, FERGUS AND BLACK HILLS RAILROAD—Continued.

	From Wadena.	Above the sea.
	Miles.	*Feet.*
Crossing St. Paul, Minneapolis and Manitoba Railway	51·2	1194
Fergus Falls	51·9	1185
Red River, bed, 1,147; water (in lowest millpond), 1,156; grade	52·2	1177
Pelican River, bed, 1,122; water, 1,124; grade	56·0	1135
Summit, grade	56·5	1177
French	58·2	1087
Upper or Herman Beach of Lake Agassiz, crest, 1,082; grade	60·0	1077
(This beach ridge is about 40 rods wide (including the slopes), and rises 10 feet above its base on each side.)		
Ames (station discontinued)	60·6	1065
Everdell	68·4	994
Watosco	71·3	980
Red River, bed, 956; grade	74·6	971
Breckenridge	76·9	962
Bois des Sioux River, bed, 944; water, 945; grade	77·2	962
Wahpeton	78·0	965
Wild Rice River, bed, 937; water, 940; grade	82·6	959
Farmington	84·9	962
Antelope Creek, grade	86·5	960
Fairview	88·4	967
Mooreton	90·8	969
McCauleyville Beach of Lake Agassiz, crest, 974; grade. (This beach ridge is about 30 rods wide; its crest is 8 feet above its east base and 3 feet above its west base)	91·1	975
Barney	96·9	1033
Wyndmere	103·8	1062
Herman Beach, crest, 1,067; grade	105·3	1066
(This beach ridge is 50 rods wide (including the slopes), and rises 8 feet above the land on each side.)		
Thence westward the surface is very nearly level for about 8 miles	105·4–113·2	1062–1066
De Lamere	112·5	1066
Milnor Beach, crest and grade the same	116·0	1085
Second (upper) Milnor Beach, crest and grade the same. (Each of these beach ridges is about 20 rods wide and 4 to 6 feet high.)	116·3	1086
Milnor	119·0	1097

DULUTH AND MANITOBA RAILROAD.

(Operated by Northern Pacific Railroad Company.)

[From profile in the offices of J. B. Holmes, president, Minneapolis, and S. D. Mason, engineer, St. Paul].

The elevations from Winnipeg Junction to Fertile are copied without change. Close north of Fertile a discrepancy in the profile requires a subtraction of 10½ feet from its elevations thence northward. With this correction, the elevations obtained by this survey at Grand Forks and Pembina are 2 feet higher than by the St. Paul, Minneapolis and Manitoba Railway west of the Red River, and by the United States Engineer Corps in their survey of this river; but they would be 4 feet higher if a uniform addition of 2 feet were made, as required to bring this profile into accord with the Northern Pacific Railroad. The addition of 2 feet is therefore omitted; and the corrected profile is harmonized with the United States engineers' surveys along the Red River by subtracting 2½ feet from it (i. e., 13 feet from the original profile) at Red Lake Falls and uniformly thence northward to Pembina and the international boundary.

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

DULUTH AND MANITOBA RAILROAD—Continued.

	From Winnipeg Junction.	Above the sea.
	Miles.	*Feet.*
Winnipeg Junction, Northern Pacific Railroad, 226·6 miles from Duluth	0·0	1181
Buffalo River, bed, 1,150; grade	0·5	1172
Summit, natural surface and grade	5·8	1253
Ulen	13·0	1154
South Branch of Wild Rice River, bed, 1,113; grade	13·6	1135
Upper or Herman Beach of Lake Agassiz, crest, 1,141; grade	18·6	1135
(Descent south from crest in 12 rods, 9 feet; descent north in 12 rods, 6 feet.)		
Twin Valley	25·8	1093
Wild Rice River, bed, about 985; grade	27·8	1010
Norman	33·9	1099
Herman Beach, crest, 1,156; grade	43·7	1151
Sand Hill River, bed, 1,075; grade	44·5	1115
Fertile	45·5	1140
Kittelson Creek, bed, 1,094; grade	48·1	1124
Herman (*b*) Beach, crest	49·3–50·0	1152–1155
Herman (*d*) Beach, three places, crest, 1,118–1,119; grade	57·0–57·8	1116–1117
Crossing the Fosston branch of the St. Paul, Minneapolis and Manitoba Railway	57·1	1116
Tilden	57·3	1116
Norcross Beach, crest and grade	61·3–61·6	1101
Tributary of Badger Creek, 1,033; grade	64·9	1045
Red Lake Falls, junction of spur track to station	68·7	1036
Red Lake Falls station, 0·6 mile from the main line	69·3	1035
Red Lake River, bed, 932; grade	70·6	964
Summit, cutting 9 feet; grade	73·0	1011
Black River, bed, 939; grade	75·9	974
McCauleyville Beach, crest and grade	76·6–77·8	993–992
Crossing the St. Hilaire branch of the St. Paul, Minneapolis and Manitoba Railway	78·3	977
Beach, crest and grade	80·7	962–961
Beach, crest and grade	81·4	954
Beach, crest and grade	82·1	946
South Euclid, crossing the St. Vincent line of the St. Paul, Minneapolis and Manitoba Railway	86·0	901
Buffington	90·0	872
Junction of spur track to Keystone	93·3	855
Lowest portions of this spur track	94·6–95·9	853
Keystone	96·3	855
Grand Marais Slough (former channel of Red Lake River), bed, 813; grade	101·6	828
East Grand Forks	104·7	831
End of spur to river, East Grand Forks	105·1	807
Red River, bed, 779; extreme low and high water, 784–828; grade	104·9	831
Grand Forks	105·4	834
Slough, bed, 807; grade	107·3	828
Salt River, bed, 817; grade	114·1	836
Kelley's	115·9	842
Salt Cooley, bed, 823; grade	116·6	835
Meckinock	122·1	861
Turtle River, bed, 854; grade	122·9	865
Bean's	127·3	893
Gilby	130·9	879
Johnstown	135·3	871
Forest River Station	140·3	862
Forest River, bed, 847; grade	141·1	859
Voss	145·5	842
Crossing the Neche line of the St. Paul, Minneapolis and Manitoba Railway	153·7	826

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

DULUTH AND MANITOBA RAILROAD—Continued.

	From Winnipeg Junction.	Above the sea.
	Miles.	*Feet.*
Grafton	154·6	824
Park River, bed, 803; grade	155·0	822
Cashel	161·9	804
Drayton	170·1	798
Bowesmont	179·1	791
Joliette	188·6	794
Pembina River, ordinary stage of water, 757; grade	198·2	785
Pembina	199·1	789
Grade on the international boundary	201·5	789

FARGO AND SOUTHWESTERN RAILROAD.

(Operated by Northern Pacific Railroad Company.)

[From profile in the office of S. D. Mason, engineer, St. Paul.]

An addition of 2 feet is made here, as on the Northern Pacific Railroad. It agrees at La Moure with the James River Valley Railroad, and at Edgeley with the Chicago, Milwaukee and St. Paul Railway.

	From Fargo.	Above the sea.
	Miles.	*Feet.*
Junction with Northern Pacific Railroad, near Fargo, 253·7 miles from Duluth	1·2	905
Cotter's	4·2	911
Horace	10·7	919
Sheyenne River, bed, 897; grade	12·3	923
Warren	16·1	926
Davenport, crossing the St. Paul, Minneapolis and Manitoba Railway	19·1	923
Woods	25·3	952
Lower Tintah Beach of Lake Agassiz, crest, 1,014; grade. (This beach ridge is bordered on its east side by a gradual slow descent, and on the west side by a depression 7 feet below its crest, 15 rods distant. Small beach ridges appear also 500 and 800 feet west from this depression, their crests being at 1,016 and 1,017 feet; grade at these points is 1,018 and 1,021.)	27·8	1010
Upper Tintah Beach or shore of Lake Agassiz, the summit of a comparatively steep ascent from the east, with a gentler ascent thence westward, escarpment crest, 1,034; grade	28·2	1029
Leonard	28·7	1047
(Norcross Beaches, three, at 32·0, 32·3, and 32·7 miles; crests, 1,062, 1,062, and 1,065 feet. The last is only 18 rods wide; the depression on its east side is 6 feet, and on the west 5 feet.)		
Depression, apparently an ancient water-course, 800 feet wide, 6 feet below the land on each side (but eastward a gradual descent begins within 500 feet), bottom, 1,064; grade	40·15–40·3	1070
Sheldon	41·5	1080
Natural surface, 1,122; grade	45·1	1119
Buttzville	50·4	1173
Summit, cutting 1 foot; grade	51·0	1190
Top of left (eastern) bluff of the Sheyenne River, natural surface and grade the same	54·0	1187
(Thence the grade descends rapidly westward, with frequent cuts and fills of 15 to 35 feet.)		

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

FARGO AND SOUTHWESTERN RAILROAD—Continued.

	From Fargo.	Above the sea.
	Miles.	*Feet.*
Sheyenne River, bed, 1,064; grade	55·8	1092
Lisbon	56·0	1091
Elliott	63·0	1310
Summit, cutting 3 feet; grade	65·5	1408
Marshall	68·5	1343
Summit, natural surface and grade the same	71·7	1385
Bear Creek, bed, 1,328; water, 1,333; grade	74·3	1352
Verona	76·5	1387
Valley Junction, James River Valley railroad	82·7	1403
La Moure, junction with James River Valley railroad	88·0	1307
James River, bed, 1,289; grade	88·4	1307
Notes of the continuation of this railroad from La Moure to Edgeley, under the name of the Northern Pacific, La Moure and Missouri River Railroad, are as follows:		
Berlin	98·0	1470
Medbery	104·1	1522
Crossing the Chicago, Milwaukee and St. Paul Railway	108·9	1553
Edgeley	109·4	1568

JAMES RIVER VALLEY RAILROAD.

(Operated by Northern Pacific Railroad Company.)

[From profile in the office of S. D. Mason, engineer, St. Paul.]

This agrees at Jamestown with the Northern Pacific Railroad and at La Moure and Valley Junction with the Fargo and Southwestern Railroad.

	From Jamestown.	Above the sea.
	Miles.	*Feet.*
Jamestown, junction with the Northern Pacific Railroad, 345.5 miles from Duluth	0·0	1408
James River, first crossing, bed, 1,361; grade	5·3	1379
Summit, natural surface and grade	6·7	1403
James River, second crossing, bed, 1,350; grade	9·8	1370
Summit, natural surface and grade	12·2	1388
Ypsilanti	12·8	1381
Gravel pit, grade	13·1–13·4	1375
James River, third crossing, bed, 1,342; grade	14·0	1364
Same, fourth crossing, bed, 1,334; grade	18·1	1357
Montpelier	18·9	1358
Line between Stutsman and La Moure Counties, natural surface and grade	23·9	1352
Adrian	26·2	1355
James River, fifth crossing, bed, 1,315; grade	30·1	1336
Dickey	32·5	1360
James River, sixth crossing, bed, 1,305; grade	35·8	1327
Same, seventh crossing, bed, 1,298; grade	39·2	1320
Grand Rapids	41·1	1321
James River, eighth crossing, bed, 1,293; grade	45·6	1310
Same, ninth crossing, bed, 1,290; grade	47·5	1307
West La Moure	48·1	1305
James River, tenth crossing, bed, 1,289; grade	48·3	1307
La Moure, junction with Fargo and Southwestern R. R.	48·7	1307
Valley Junction, Fargo and Southwestern R. R	54·0	1403
Glover	61·7	1373
Bear Creek, bed, 1,287; grade	67·6	1303
Oakes, connection with the Chicago and Northwestern Railway	69·1	1313

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

SANBORN, COOPERSTOWN AND TURTLE MOUNTAIN RAILROAD.

(Operated by Northern Pacific Railroad Company.)

[From profile in the office of S. D. Mason, engineer, St. Paul.]

With addition of 2 feet, as on the Northern Pacific Railroad.

	From Sanborn.	Above the sea.
	Miles.	*Feet.*
Sanborn, junction with Northern Pacific Railroad, 322·0 miles from Duluth	0·0	1444
Odell	9·0	1426
Dazey	18·0	1433
Hannaford	27·5	1382
Cooperstown	36·5	1428

JAMESTOWN AND NORTHERN RAILROAD.

(Operated by Northern Pacific Railroad Company.)

[From profile in the office of S. D. Mason, engineer, St. Paul.]

With addition of 2 feet, as on the Northern Pacific Railroad. It agrees at Devil's Lake with the St. Paul, Minneapolis and Manitoba Railway.

	From Jamestown.	Above the sea.
	Miles.	*Feet.*
Junction with Northern Pacific Railroad 1 mile west of Jamestown, 346·5 miles from Duluth	1·0	1399
Pipestem Creek, bed, 1,388; grade	1·6	1405
Same, bed, 1,394; grade	2·6	1410
Parkhurst	6·5	1502
Buchanan	13·5	1548
Pingree	21·1	1550
Edmunds	27·6	1597
Melville	34·5	1603
Carrington	43·5	1584
Junction of branch to Sykeston	44·0	1586
Barlow	50·8	1545
New Rockford	59·5	1531
James River, bed, 1,499; water, 1,502; grade	60·0	1516
Summit, natural surface and grade the same	66·0	1611
Sheyenne	70·6	1480
Sheyenne River, bed, 1,409; water, 1,410; grade	72·1	1423
Oberon	79·3	1559
Fort Totten Station	83·2	1566
Minnewaukan	90·1	1461
Devil's Lake, water Aug. 10, 1887	90·1	1431·5
Same, lowest and highest stages during years 1880 to 1889	90·1	1430–1434
BRANCH TO SYKESTON.		
Junction with the preceding, near Carrington	44·0	1586
Pipestem Creek, bed, 1,562; water, 1,563; grade	50·0	1582
Ross	50·5	1591
Sykeston	57·0	1628

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

ROCKY MOUNTAIN RAILROAD OF MONTANA

(To the Yellowstone National Park.)

[Note.—This and the following lines are operated by the Northern Pacific Railroad Company, and are copied from profiles in the office of S. D. Mason, engineer, St. Paul. Two feet are added uniformly to them all, as on the Northern Pacific Railroad.]

	From Livingston.	Above the sea.
	Miles.	*Feet.*
Livingston, junction with the Northern Pacific Railroad, 1,008·2 miles from Duluth	0 0	4457
Brisbin	10·0	4682
Trail Creek Station	14·2	4822
Chicory	20·0	4847
Emigrant	23·0	4862
Dailey's	30·5	4915
Sphinx	41·2	5072
Cinnabar	51·0	5172

HELENA AND JEFFERSON COUNTY RAILROAD.

	From Prickly Pear Junction.	Above the sea.
	Miles.	*Feet.*
Prickly Pear Junction, with Northern Pacific Railroad, 1,126·3 miles from Duluth	0·0	3889
Clancy	9·7	4317
Jefferson Junction, with Helena, Boulder Valley and Butte Railroad	15·2	4515
Jefferson	15·5	4537
Corbin	17·3	4752
Wickes	20·0	5152

HELENA, BOULDER VALLEY AND BUTTE RAILROAD (BRANCH FROM THE LAST).

	From Jefferson Junction.	Above the sea.
	Miles.	*Feet.*
Jefferson Junction	0·0	4515
Hodgson	3·0	4858
Boulder Pass, summit, 5,715; grade in tunnel (192 feet long)	8·6	5662
Boulder City	17·0	4920
Cataract	24·6	5274
Calvin	30·0	5556

HELENA AND RED MOUNTAIN RAILROAD.

	From Helena.	Above the sea.
	Miles.	*Feet.*
Helena, 1,131·2 miles from Duluth	0·0	3932
Red Mountain Junction, with Northern Pacific Railroad.	1·9	3909
Kessler's	3·2	3930
Thermal Springs	4·7	4027
Gold Bar	11·0	4490
Moose Creek Station	14·1	4831
Rimini	16.9	5183

NORTHERN PACIFIC RAILROAD SYSTEM—Continued.

HELENA AND NORTHERN RAILROAD.

	From Clough Junction.	Above the sea.
	Miles.	*Feet.*
Clough Junction, with Northern Pacific Railroad, 1,140·6 miles from Duluth	0·0	4315
Cruse	6·4	4585
Marysville	12·4	5376

DRUMMOND AND PHILLIPSBURG RAILROAD.

	From Drummond.	Above the sea.
	Miles.	*Feet.*
Drummond, junction with Northern Pacific Railroad, 1,202·7 miles from Duluth	0·0	3945
New Chicago	2·9	4037
Stone	12·3	4539
Flint	15·7	4814
Phillipsburg	25·8	5167

MISSOULA AND BITTER ROOT VALLEY RAILROAD.

	From Missoula.	Above the sea.
	Miles.	*Feet.*
Missoula, junction with Northern Pacific Railroad, 1,255·5 miles from Duluth	0·0	3197
Missoula River, low water, 3,159; grade	0·5	3178
Bitter Root River, low water, 3,112; grade	4·4	3132
Lou Lou	11·0	3175
Florence	20·0	3249
Stevensville	27·7	3299
Victor	35·5	3391
Corvallis	44·0	3474

CANADIAN PACIFIC RAILWAY SYSTEM.

A published profile of this railway gives the elevation of Lake Superior as 598 feet above the sea, while on the profiles in the engineers' offices it is shown as 600 feet. Assuming the mean of these figures to represent the mean lake level, a uniform addition of 3 feet is here made to the eastern part of the profile, extending from Port Arthur to Eagle River Station, to accord approximately with the mean elevation of Lake Superior, 601·56 feet, determined by the engineers of the United States Lake Survey.

The profile shows a discrepancy of 8 feet close west of Eagle River Station, 232 miles west of Port Arthur, on account of which its elevations thence west to Cross Lake require a substraction of 5 feet, which is here made, to agree with the foregoing. Again at Cross Lake, 334·4 miles west of Port Arthur, a discrepancy of 5 feet to be added is found in the profile, so that its original elevations thence west to the Red River and south to Emerson are here copied without change, being in accord with the corrected profile on the east.

The main line from East Selkirk to the junction of the Emerson branch, close east of Winnipeg, and this branch, extending from St. Boniface to the international boundary, are supplied by Collingwood Schreiber, chief engineer and general manager of the Canadian government railways, and are on the same system of leveling with the main line from Port Arthur to East Selkirk, which, however, is subject to the slight adjustments mentioned. This whole series thus adjusted is surely correct within very close approximation, as is shown by its exact agreement at Emerson with the St. Paul, Minneapolis and Manitoba Railway, and with leveling by the United States Engineer Corps along the Red River of the North.

Two smaller discrepancies also appear in this profile, but are here neglected. At 117 miles from Port Arthur (close west of Scott's River), and thence west, a subtraction of 2 feet is indicated; and at 256·5 miles (close west of Parrywood), and thence west, a subtraction of 1 foot. If those were taken into account the west part of this profile would be lowered 3 feet; but it seems more probable that it should agree with the elevation of Emerson, determined by surveys in the United States.

A large discrepancy is found between this eastern system of leveling and that which begins at Winnipeg and extends west to the Rocky Mountains. The latter includes the branches west of the Red River at Winnipeg and westward, also the Manitoba and Northwestern Railway and its branches, which refer their elevations to that of the Canadian Pacific profile at Portage la Prairie. The system east of the Red River is reliable, as already stated; and leveling from St. Boniface Station (754) to the Louise Bridge (752, instead of 728 on the profile extending westward) shows that the system west of the Red River requires a uniform addition of 24 feet, which is here made in these lists of altitudes at Winnipeg and thence west. With this correction, the Southwestern branch from Winnipeg to Gretna agrees with the St. Paul, Minneapolis and Manitoba Railway at the international boundary; the survey from this branch at Rosenfeld to Emerson agrees with the Emerson branch; and the West Selkirk branch agrees with the main line east of the Red River.

MAIN LINE, FROM PORT ARTHUR TO WINNIPEG.

[Between Port Arthur and East Selkirk, from profiles in the offices of P. A. Peterson, engineer, Montreal, and R. M. Pratt, engineer, Winnipeg; and between East Selkirk and Winnipeg from Collingwood Schreiber, engineer of Government railways, Ottawa.]

	From Port Arthur.	Above the sea.
	Miles.	*Feet.*
Lake Superior, mean, 1871–1887	0·0	601.56
Port Arthur (a summit of grade), 993·0 miles from Montreal	0·0	628
McIntyre or Second River, water, 603; grade	6·0	610
Neebing or First River, water, 603; grade	6·2	610
Fort William	7·0	615
(Kaministiquia River here, 1¼ miles above its mouth, bed, 586; low water (1879), 600; high water (1859), 612.)		
Fort William West (station disused)	10·0	635
(Kaministiquia River here, bed, 584; low and high water, 602–614.)		
Murillo	17·6	947
Summit, grade (2 feet above natural surface)	20·6	1080
Lofoden	20·8	1078
Depression, filling 7 feet; grade	21·8	1055
Summit, cutting 2 feet; grade	22·3	1081
Strawberry Creek, bed, 987; low and high water, 990–993; grade	27·3	1002
Kaministiquia	27·9	1013
Kaministiquia River, bed, 973; low and high water, 982–996; grade	28·2	1013
Mattawan River, bed, 1,078; low and high water, 1,082–1,089; grade	32·4	1099
Sunshine Creek, first crossing, bed, 1,106; low and high water, 1,109–1,113; grade	33·9	1122
Same, third crossing, bed, 1,151; low and high water, 1,158–1,162; grade	35·5	1168
Finmark	37·1	1180
Sunshine Creek, bed, 1,330; water, 1,334; grade	41·3	1352
Buda (a summit, natural surface and grade the same)	44·4	1473
Oskondiga River, bed, 1,415; water, 1,421; grade	45·3	1453
Tunnel, grade, 51 feet below top of rock above	46·1	1458
Oskondiga River, bed, 1,426; water, 1,428; grade	52·2	1441
Nordland	55·5	1543
Summit, natural surface and grade	57·8	1584
Southeast branch of Savanne River, bed, 1544; water, 1545; grade	59·9	1554
Same, bed, 1,537; water, 1,538; grade	62·0	1546
Linkooping	65·2	1534

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM PORT ARTHUR TO WINNIPEG—Continued.

	From Port Arthur.	Above the sea.
	Miles.	*Feet.*
Savanne	75·8	1506
North branch of Savanne River, bed, 1,487; water, 1,489; grade	76·4	1506
Upsala	86·2	1579
Carlstad	93·6	1515
Fire-steel River, bed, 1500; water, 1,505; grade	98·5	1513
Beaver River, bed, 1,519: water, 1,525; grade	102·2	1532
Bridge River Station	103·6	1543
Hawk Lake, water, 1,509; grade	113·6	1518
English River, bed, 1,504; water, 1,510; grade	115·2	1515
English River Station	116·0	1517
Scott's River, bed, 1,505; water, 1,511; grade	116·6	1516
Summit, cutting 11 feet; grade	123·6	1558
Martin	124·0	1557
Depression, grade	127·4	1483
Summit, grade	131·6	1549
Bonheur	134·0	1530
Summit, grade	136·4	1554
South Lake, water, 1,495; grade	138·3	1510
Depression, grade	139·7	1478
Gull River, bed, 1,456; grade	143·7	1490
Falcon	144·8	1509
Abgimac River, bed, 1,470; grade	151·3	1490
Ignace	152·3	1487
Osaquan River, bed, 1,398; grade	158·7	1420
Butler	160·5	1423
Little Wabigoon River, bed, 1,398; grade	165·7	1408
Gleucoe River, bed, 1,398; grade	167·0	1405
Raleigh	170·4	1440
Little Wabigoon River, bed, 1,350; grade	180·0	1366
Taché	180·2	1366
Burnt Stick Creek, bed, 1,314; grade	182·5	1347
Kirkpatrick Creek, bed, 1,320; grade	183·9	1352
Bear Creek, bed, 1,333; grade	186·6	1348
Brulé	190·4	1355
McHugh's Creek, bed, 1,207; grade	198·6	1235
Summit, grade	200·4–200·8	1255
Hughes River, bed, 1,198; grade	202·2	1211
Wabigoon	202·6	1211
Blackwater Creek, bed, 1,200; grade	204·5	1211
Thunder Creek, bed, 1,205; grade	206·1	1225
Barclay	209·8	1251
Summit, cutting 10 feet; grade	211·5	1267
Wabigoon River, bed, 1,178; grade	215·4	1219
Shoshogawae River, bed, 1,151; grade	220·8	1159
Oxdrift	221·8	1162
Beaver River, first crossing, bed, 1,129; grade	225·8	1149
Same, second crossing, bed, 1,125; grade	226·4	1139
Same, third crossing, bed, 1,123; grade	229·4	1153
Eagle River Station	231·8	1186
Eagle River, bed, 1,148; grade	232·2	1190
Summit, cutting 7 feet; grade	234·9	1278
Vermilion Bay Station	242·0	1221
Grass Creek, bed, 1,183; grade	242·5	1213
Eagle Lake, water, about 1,182; grade	246·9	1210
Gilbert	249·8	1217
Muskrat Lake, water, about 1,174; grade	251·0	1206
Summit, natural surface and grade	255·4	1295
Parrywood	256·3	1292
Stewart Lake, water, 1,303; grade	258·3	1328
Summit near Forest Lake, natural surface and grade	259·8	1382
Outlet of Swan Lake, bed, 1,332; grade	260·8	1362

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM PORT ARTHUR TO WINNIPEG—Continued.

	From Port Arthur.	Above the sea.
	Miles.	*Feet.*
Parrywood Lake, water, about 1,362; grade (a summit)	262·1	1379
Outlet of Ulverston Lake, bed, 1,318; grade	262·9	1364
Mud Lake, water, 1,328; grade	263·3	1355
Feist Lake, water, 1,326; grade	264·3	1347
Turtle Lake, water, 1,366; grade	265·1	1376
Summit Station, cutting near, 10 feet; grade	265·4	1385
Summit Lake, water, 1,384; grade	265·6	1385
Clare Lake, water, 1,284; grade	270·3	1295
Viaduct Lake, water, 1,246; grade	271·6	1282
Hawk Lake Station	272 9	1289
Outlet of Narrow Lake, bed, 1,220; grade	275·1	1256
Trout Lake Creek, bed, 1,213; grade	280·6	1248
Beaver (depression of grade near Beaver Dam Lake)	284·1	1186
Rossland	288·9	1128
Rat Portage	297·3	1087
Winnipeg River, outlet of the Lake of the Woods, low water, at same level with this lake, 1,057; grade	298·1	1087
Lake of the Woods, mean, 1,060; low and high water	298·1	1057–1063
(Dr. A. C. Lawson states that this lake "has a rise and fall through a range of 10 feet."—Geol. Survey of Canada, Ann. Rep., 1885, p. 18 CC.)		
Keewatin	300·8	1075
Winnipeg Bay, water, 1,043; grade	301·6	1062
Mink Bay, water, 1,043; grade	302·4	1070
Winnipeg Bay, water, 1,043; grade	303·7	1078
War Eagle Lake, water, 1,082; grade	305·8	1121
Ostersund	308·3	1105
Summit, cutting 33 feet; grade	311·4	1187
Lake Bobo or Helen, water, 1,138; grade	312·7	1151
Lake Deception, water, 1,094; grade	313·1	1143
Deception	313·4	1136
Bear or Greenwater Lake, grade	315·2	1192
Summit, at west end of a cut 35 feet deep; grade	315·7	1218
Monument Lake, grade	318·3	1218
Red Pine Lake, grade	319·2	1226
Fellows Lake, water, 1,235; grade (11 feet lower than the lake)	319.7	1224
Kalmar	320·4	1217
Summit Lake, water. 1,252; grade	322·1	1255
Kennedy Lake, water, 1,245; grade (2 feet lower than the lake)	323·1	1243
White Fish Lake, water, 1,213; grade	323·8	1243
Summit, 30 rods west from the center of a cut 33 feet deep; grade	325·8	1221
Ingolf	328·2	1184
Summit, cutting 30 feet; grade	328·9	1190
Cross Lake Station, water, 1,045; grade	334·4	1092
Depression, grade	336 2	1053
Telford	338·5	1059
Summit, grade, 2 feet above the natural surface	342·3	1115
For 2½ miles east and 1 mile west the surface is very smooth		1105–1113
River Brenton, water, 1,041; grade	348·7	1050
Rennie	349·0	1053
Bog River, water, 996; grade	354·7	1007
Same, water, 993; grade	356·2	996
Darwin	359·4	971
(Westward to the Red River the country is mostly swamp, bearing alders and tamaracks. The swamp is underlaid by a hard bottom at depths varying commonly from 5 to 15 feet.)		
Bog River, water, 927; grade	364·0	935

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM PORT ARTHUR TO WINNIPEG—Continued.

	From Port Arthur.	Above the sea.
	Miles	*Feet.*
Whitemouth River, water, 877; grade	368·1	900
Whitemouth	368·9	907
Beaver Creek, water, 885; grade	369·8	904
Shelly	374·9	929
Monmouth	384·9	879
Bear Creek, water, 820; grade	387·4	831
Broken Head River, water, 784; grade	391·1	796
Beausejour	394·3	814
Tyndall	400·9	796
Devil's Creek, water, 770; grade	402·3	777
East Selkirk	408·9	743
(Red River at West Selkirk, 2 miles west from East Selkirk, "ice, 1876" (probably 2 or 3 feet above extreme low water), 712; flood of 1876, 723; flood of 1875, 725; extreme high water, flood of 1826, 732. The railway at East Selkirk turns southward, leaving the line of its original survey, which crossed the Red River here.)		
Extreme range in height of river	411·0	710–732
Lake Winnipeg, mean, 710; low and high water, approximately	.....	708–713
Cook's Creek, water	409·1	728
Gonor	415·0	757
Bird's Hill Station	422·1	759
Winnipeg Junction, Emerson Branch	427·8	752
Red River, extreme low water, 723; highest water in ordinary years, 735–740; high water, 1882, 749; grade, Louise Bridge	429·0	752
Winnipeg	429 8	757

MAIN LINE, FROM WINNIPEG TO THE ROCKY MOUNTAINS AND DONALD.

[From profile in the office of R. M. Pratt, engineer, Winnipeg. This profile was carefully revised after the construction of the road, and seems entitled to entire confidence.]

With uniform addition of 24 feet (page 40).

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Winnipeg, 1,422·8 miles from Montreal	0·0	757
Junction of Southwestern Branch	1·1	760
Junction of Manitoba and Southwestern Railway	1·2	760
Junction of West Selkirk Branch	1·5	759
Point of beginning of the original profile (at 0 of distances measured thence westward)	1·8	761
Air Line Junction, of Stonewall Branch	1·9	761
Colony Creek, water, 769; grade	3·3	776
Same, water, 772; grade	4·0	780
Junction of Winnipeg and Hudson Bay Railway	4·7	780
Bergen	7·4	784
Rosser	15·2	796
Meadows	22·3	793
Marquette	28·9	807
Reaburn	35·2	806
Long Lake, ordinary low and high water, 798–803; grade	35·7	804
Poplar Point	40·4	815
High Bluff	48·7	829
Portage la Prairie, junction of the Manitoba and Northwestern Railway	56·0	854

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM WINNIPEG TO THE ROCKY MOUNTAINS AND DONALD—Con

	From Winnipeg.	Above t
	Miles.	*Fe*
Dry Creek, bed, 858; grade	63·4	
Burnside	63·5	
Rat Creek, water, 862; grade	65·1	
Bagot	71·1	
Image Creek, water, 939; grade	75·6	
McGregor	77·6	
Austin	84·5	
Lower Campbell (*b*) Beach of Lake Agassiz, crest, 1,066; grade	86.9	
Upper Campbell (*aa*) Beach, crest, 1,081; grade	87·2	
Upper Campbell (*a*) Beach, crest, 1,087; grade	87·5	
(These beach ridges are each about 30 rods wide, with descents of 10 to 20 feet from their crests to their east bases and half as much to the west. A very uneven profile, intersected by numerous ravines, extends from 89·3 to 92 miles, in which distance the grade rises upon the front of the Assiniboine Delta of Lake Agassiz from 1,124 to 1,232 feet.)		
Sydney	92·6	
(It is again very uneven from 93·7 to 95·9 miles, in which distance the grade ranges from 1,234 to 1,251 feet, crossing low dunes on the delta plain. Here and westward the profile shows frequent lakelets, but no names of them are given.)		
Melbourne	98·0	
Pine Creek, water, 1,199; grade	99·7	
(Uneven surface of low dunes extends from 101·1 to 102·7 miles, the grade ranging from 1,244 to 1,257 feet.)		
Carberry	105·5	
Herman (*dd*) Beach of Lake Agassiz, crest, 1,263; grade	107·6	
Herman (*d*) Beach, crest, 1,268; grade	108·9	
(Each of these beach ridges is about 25 rods wide, with crest about 5 feet above the adjoining land; but west of the west beach (*d*) is a depression of 10 to 12 feet, about 50 rods wide, succeeded farther west by land slightly—only a few feet—above these beaches. Very uneven contour of dune sand reaches from 110·2 miles (grade, 1,274) to 112·7 miles (grade, 1,249.)		
Sewell	114·2	
(Two slight summits of grade, probably crests of the Herman (*d*) Beach, natural surface and grade the same (1,268 feet), are crossed at 116·3 and 116·8 miles.)		
Douglas	121·5	
Chater	127·2	
Assiniboine River, water, 1,161; grade	131·0	
Brandon	132·7	
Kemnay	140·9	
Alexander	148·4	
Griswold	157·4	
Flat Creek, water, 1,376; grade	162·4	
Oak Lake Station	164·7	
Gopher Creek, water, 1,404; grade	178·9	
Virden	180·0	
Hargrave	188·1	
Elkhorn	196·6	
Fleming	210·8	
Moosomin	219·1	
Red Jacket	226·4	

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM WINNIPEG TO THE ROCKY MOUNTAINS AND DONALD—Continued.

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Wapella	235·2	1930
Burrows	242·8	1948
Whitewood	249·2	1966
Percival	256·2	2038
Summit, grade	257·9	2054
Broadview	263·8	1960
Oakshela	272·0	1952
Grenfell	279·9	1957
Summerberry	287·4	1938
Wolseley	295·1	1950
Sintaluta	303·9	1984
Indian Head	314·1	1924
Qu' Appelle	323·8	2134
McLean	332·4	2284
Summit, grade	334·3	2286
Balgonie	341·5	2187
Pilot Butte	348·0	2016
Regina, junction of the Regina and Long Lake Railway	356·6	1885
Pile of Bones Creek (Wascana River), grade	358·6	1861
Grand Coulée Station	366·1	1857
Grand Coulée (creek), grade	368·7	1842
Pense	373·5	1881
Belle Plaine	381·3	1902
Pasqua	390·2	1872
Moose Jaw Creek, grade	398·1	1761
Moose Jaw	398·3	1767
Boharm	406·5	1792
Caron	414·5	1841
Mortlach	423 6	1961
Parkbeg	432·8	1982
Summit, grade	442·9	2282
Secretan (on the Missouri Cotean)	443·2	2282
Chaplin	452·0	2202
Ernfold	461·4	2288
Summit, grade	464·2	2374
Morse	471·8	2274
Herbert	480·6	2311
Summit, grade	485·2	2377
Rush Lake Station	489·3	2301
Summit, grade	495·4	2420
Waldec	496·7	2357
Aiken's	504·8	2401
Swift Current Creek, grade	509·7	2415
Swift Current Station	510·6	2423
Leven	519·6	2467
Goose Lake Station	528·9	2465
Summit, grade	532·3	2586
Depression, grade	533·7	2542
Summit, grade	535·5	2590
Antelope	538·5	2556
Gull Lake Station	546·3	2562
Cypress	554·8	2637
Sidewood	565·4	2478
Crane Lake Station	575·5	2518
Summit, grade	583·9	2568
Colley	585·9	2509
Summit, grade	589·2	2561
Maple Creek Station	596·7	2495
Maple Creek, grade	597·2	2497
Kincarth	605·9	2531
Summit, grade	608·9	2546
Forres	615·5	2428
Walsh	627·9	2430

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM WINNIPEG TO THE ROCKY MOUNTAINS AND DONALD—Co

	From Winnipeg.	Above
	Miles.	*Fe*
Summit, grade	636·4	
Irvine	638·3	
Dunmore, junction of the Northwest Coal and Navigation Company's Railway	652·8	
Medicine Hat	660·3	
South Saskatchewan River, low and high water, 2,137–2,154; grade	660·6	
Stair	667·3	
Bowell	675·1	
Summit, grade	675·7	
Depression at tank, grade	682·6	
Suffield	686·6	
Langevin (a summit of grade)	695·2	
Kininvie	704·1	
Tilley	713·3	
Summit, grade	719·3	
Bantry	723·1	
Tank, 4 miles west of last	727·1	
Cassils	733·1	
Southesk	740·7	
Lathom	748·9	
Bassano	757·5	
Summit, grade	764·4	
Crowfoot	765·9	
Summit, a half mile east of tank	768·4	
Crowfoot Creek, grade	770·1	
Cluny	776·5	
Gleichen	784·8	
Summit, grade	790·0	
Nanaka	793·8	
Summit, near tank	796·2	
Strathmore	801·0	
Cheadle	809·4	
Summit, grade	815·0	
Langdon	819·5	
Summit, grade	824·8	
Depression, grade	828·2	
Shepard	830·1	
Summit, grade	832·9	
Bow River, grade	836·8	
Elbow River, water, 3394; grade	839·2	
Bow River, at the mouth of Elbow River, water	839·2	
Calgary	840·1	
Keith	849·4	
Cochrane	862·9	
Radnor	873·1	
Morley	881·6	
Kananaskis River, bed	892·0	
Kananaskis	894·1	
The Gap, station	901·9	
Bow River here, at point of issue from the mountains, water, about	901·9	
Branch of Bow River, water	902·3	
Canmore	907·2	
Bow River, water	914·5	
Duthil	914·8	
Devil's Head Creek, water	916·1	
Anthracite	917·3	
Banff (new station)	921·8	
Forty-Mile Creek, water	922·0	

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE, FROM WINNIPEG TO THE ROCKY MOUNTAINS AND DONALD—Continued.

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Cascade	927·9	4531
Bow River, water	934·2	4586
Castle Mountain, station	938·6	4653
Eldon	946·3	4804
Baker's Creek, water	948·6	4852
Lion Creek, water, 4,949; grade	954·2	4970
Laggan	956·2	5029
North Branch of Bow River, water	956·2	5020
South Branch of Bow River, water	957·8	5049
Bath Creek, water	961·3	5263
Summit of grade crossing the Rocky Mountains, Wapta or Kicking Horse Pass	962·2	5323
Stephen	962·7	5313
Summit Lake, water	962·7	5308
Hector	965·0	5197
Kicking Horse Lake, water	965·0	5190
Kicking Horse River, first crossing, water	966·2	5184
Mount Stephen tunnel, grade	970·4	4335
Field	973·2	4058
Muskeg Summit, grade	975·7	4164
Ottertail Creek, water, 3,746; grade	978·4	3856
Ottertail	980·2	3689
Kicking Horse River, water	981·4	3665
Leanchoil	986·4	3570
Summit, grade	988·6	3669
Kicking Horse River, fourth crossing, water	992·7	3287
Palliser	994·2	3275
Kicking Horse River, sixth crossing, water, 2,666; grade	1003·5	2682
Golden	1006·7	2570
Columbia River here, at the mouth of Kicking Horse River, water	1006·7	2557
Arm of Columbia River, water	1008·7	2538
Moberly House	1013·4	2537
Blueberry Creek, water	1016·7	2544
Donald	1023·6	2565
Columbia River, first crossing, grade	1024·4	2544

MAIN LINE THROUGH BRITISH COLUMBIA, FROM DONALD TO VANCOUVER.

From H. Abbott, superintendent of the Pacific division, Vancouver, whose figures, referred to the level of the Pacific Ocean, are given without change in the first column of these elevations, showing at Donald a discrepancy of 39 feet above the preceding series from Winnipeg, Lake Superior, and the Atlantic. In the second column these figures are revised by subtraction of 39 feet from the east end of the series for agreement at Donald; by comparison with a profile from Donald to Sicamous, supplied by P. A. Peterson, engineer, Montreal, which indicates that this correction should be reduced to 30 feet at Glacier House and onward, and to 20 feet at Twin Butte and onward; and by comparison with elevations supplied by Dr. G. M. Dawson, copied from profiles in the office of Collingwood Schreiber, engineer of government railways, Ottawa, which seem to require a continuance of this subtraction of 20 feet west to Notch Hill and Shuswap, beyond which they indicate that the elevations received from Mr. Abbott are probably correct. This line, however, needs verification by leveling from Donald to Lytton, about 300 miles, within which distance the discrepancy of 39 feet noted at Donald can probably be eliminated. At Lytton, and through the remaining distance of about 150 miles to Vancouver, these elevations agree with those published by Dr. Dawson in advance sheets of the second edition of Macfarlane's American Geological Railway Guide, and with the blue print condensed profile prepared in the engineer's office of this railway, Montreal.

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

MAIN LINE THROUGH BRITISH COLUMBIA, FROM DONALD TO VANCOUVER.

	From Winnipeg.	Above the sea (Abbott).	Above the sea (revised).
	Miles.	*Feet.*	*Feet.*
Donald	1023·6	2604	2565
Beaver	1035·6	2453	2414
Six-Mile Creek Station	1041·0	2633	2594
Bear Creek Station	1050·0	3680	3641
Rogers Pass Station	1055·0	4222	4183
Summit grade in Rogers Pass, crossing the Selkirk Mountains	1056·5	4366	4327
Glacier House Station	1059·0	4102	4072
Ross Peak siding	1065·5	3471	3441
Illecillewaet	1074·5	2740	2710
Albert Canyon Station	1081·0	2244	2214
Twin Butte Station	1091·0	1918	1898
Revelstoke (at the second crossing of the Columbia River)	1103·0	1515	1495
Summit grade in Eagle Pass, crossing the Gold range	1111·0	1848	1828
Clanwilliam	1112·0	1827	1807
Griffin Lake Station	1120·0	1537	1517
Craigellachie	1130·5	1259	1239
Sicamous Bridge, crossing narrows of Shuswap Lake, 1,173 (1,153); Sicamous Station	1147·0	1171	1151
Salmon Arm	1166·0	1175	1155
Tappen siding	1173·5	1168	1148
Notch Hill Station (Shuswap summit)	1183·0	1708	1688
Shuswap	1198·5	1173	1153
Duck's	1214·5	1150	.....
Kamloops	1231·5	1153	.....
Tranquille	1239·5	1134	.....
Cherry Creek Station	1245·5	1134	.....
Savona's	1256·5	1158	.....
Penny's	1262·5	1252	.....
Ashcroft	1276·5	996	.....
Spatsum	1291·5	854	.....
Spence's Bridge Station	1303·5	768	.....
Drynock	1309·5	752	.....
Lytton	1325·5	687	.....
Cisco	1331·5	58	.....
Keefer's	1341·5	555	.....
North Bend	1352·5	487	.....
Spuzzum	1367·5	394	.....
Yale	1379·5	217	.....
Hope	1393·5	208	.....
Ruby Creek Station	1401·5	94	.....
Agassiz	1411·5	52	.....
Harrison	1420·5	38	.....
Nicomen	1429·5	23	.....
Mission	1439·5	33	.....
Wharnock	1449·5	14	.....
Hammond	1457·5	19	.....
Port Moody	1469·5	5	.....
Hastings	1478·0	22	.....
Vancouver, 2,904·8 miles from Montreal	1482·0	3	.....

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

EMERSON BRANCH.

[From Collingwood Schreiber, engineer of government railways, Ottawa.]

It agrees with the St. Paul, Minneapolis and Manitoba Railway on the international boundary (page 39).

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Winnipeg	0·0	757
Red River, grade on Louise Bridge	0·8	752
Winnipeg Junction (of this branch with the main line)	2·0	752
St. Boniface, 429·6 miles from Port Arthur	3·0	754
River Seine, high water	10·5	760
St. Norbert	12·0	767
Niverville	23·5	774
Rat River, low water, 752; high water	30·0	763
Otterburne	30·6	779
Dufrost	39·0	791
Arnaud	47·0	794
Roseau River, low water, 761; extreme high water, 1880	54·5	779
Dominion City	55·0	785
Joe River, low water, 756; high water	62·6	785
Emerson, 391·1 miles from St. Paul	65·0	790
Grade on the international boundary, connection with the St. Paul, Minneapolis and Manitoba Railway	65·1	790

SOUTHWESTERN BRANCH.

[From R. M. Pratt, engineer, Winnipeg; and west of Manitou in part from profile in the office of P. A. Peterson, engineer, Montreal.]

The profile requires a uniform addition of 24 feet (page 40), which is made here. It agrees near Gretna and at Emerson with lines of the St. Paul, Minneapolis and Manitoba Railway on the international boundary, and at Thornhill with leveling from Park River, North Dakota, in the survey of the beaches of Lake Agassiz.

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Winnipeg, 1,422·8 miles from Montreal	0·0	757
Junction of this branch with the main line	1·1	760
St. James	3·6	761
Assiniboine River, ordinary low and high water	3·7	736–754
La Salle (or Stinking) River, ordinary low and high water	18·3	737–750
La Salle Station	18·5	770
Scratching River (Rivière aux Gratias), low and high water	42·0	744–770
(The upper part of this stream, above the marshes, in which it is lost in T. 7, Rs. 2, 3, and 4, is called Boyne River, Rivière aux Iles du Bois.)		
Morris	42·8	772
Rosenfeld, junction of lines to the south and west	56·2	796
On the line south from Rosenfeld:		
Gretna	70·1	829
Grade on the international boundary, connection with the Neche line of the St. Paul, Minneapolis and Manitoba Ry	70·4	830

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

SOUTHWESTERN BRANCH—Continued.

	From Winnipeg.	Above the
	Miles.	*Feet.*
On the line (abandoned) from Rosenfeld to Emerson:		
Crossing the first initial meridian, grade	62·1	
Marais River (Rivière aux Marais), bed	68·9	
West Lynne	75·7	
Red River, low and high water	77·0	750
Emerson	77·2	
On the line west from Rosenfeld:		
Morden	80·6	
Thornhill	87·9	
Summit, grade	94·4	
Darlingford	95·9	
Summit, grade	99·4	
Manitou	102·4	
(In the descent from the top of the bluff of the Pembina River Valley at 106 miles (grade, 1,552) to its bottom at 112 miles, the profile is very irregular, with frequent cuts 10 to 50 feet deep and fills of 10 to 30 feet.)		
La Rivière	112·5	
Pembina River, water, 1,287; grade	112·7	
(Ascending from the Pembina Valley, the profile is broken by many ravines to 119 miles, where grade at the top of the bluff is 1,547 feet. The width of this valley is 1 to 2 miles.)		
Pilot Mound	125·2	
Summit, grade	125·9	
Crystal City	130·0	
Crystal Creek, water, 1,474; grade	130·6	
Summit, natural surface and grade	132·2	
Clearwater, water of Clearwater Creek (Cypress River), 1,426; grade at station	134·1	
(Smoothly undulating contour reaches from 137 to 141 miles, with grades from 1,515 to 1,532 feet; also between 141 and 147 miles, with grades from 1,525 to 1,535 feet.)		
Cartwright	144·9	
Badger Creek, water, 1,476; grade	147·6	
(Moderately undulating surface extends thence to 156 miles, the highest grades being 1,535 to 1,551 feet.)		
Holmfield	155·4	
Long River (White Mud River), water, 1,541; grade	155·7	
(Thence the line rises gradually westward to 169·4 miles, where the natural surface and grade are 1,649 feet.)		
Killarney	164·1	
Little Pembina Station	169·7	
Pembina River, water, 1,605; grade	170·3	
(The valley here is only 40 feet deep and about 40 rods wide.)		
Lake, water, 1,636; grade	171·7	
Lake, water, 1,645; grade	172·2	
Summit, level grade	181·1–181·7	
Boissevain	182·7	
Whitewater Lake, low and high water	192·7	1632-
Deloraine	202·7	
(The last 25 miles of this line lie near the northern base of Turtle Mountain.)		

CANADIAN PACIFIC RAILROAD SYSTEM—Continued.

MANITOBA AND SOUTHWESTERN RAILWAY.

(Operated by the Canadian Pacific Railway Company.)

[From R. M. Pratt, engineer, Winnipeg; and west of Elm Creek in part from profile in the office of P. A. Peterson, engineer, Montreal; with uniform addition of 24 feet (page 40).]

	From Winnipeg.	Above the sea.
	Miles.	*Feet.*
Winnipeg	0·0	757
Junction with Canadian Pacific Railway	1·2	760
Colony Creek, bed	2·8	758
Sturgeon Creek, low water	7·5	756
Assiniboine River, low and high water	14·0	754–764
Headingly	14·2	776
La Salle River, low and high water	26·8	766–774
Starbuck	27·2	781
Elm Creek Station, junction of Carman Branch	45·0	819
On the Carman Branch:		
Maryland (on the Burnside beach of Lake Agassiz)	47·5	844
Barnsley (end of track)	51·0	854
End of grade, 1 mile north of Carman	56·0	861
Boyne River (Rivière aux Iles du Bois), low and high water	56·5	842–854
On the main line west from Elm Creek Junction:		
Burnside Beach of Lake Agassiz, crest, 815; grade	46·1	841
(The descent from the crest eastward is 10 feet in 25 rods, and westward 7 feet in an equal distance.)		
Slough, water, 965; grade	57·8	967
Slough, water, 1,004; grade	61·7	1016
Slough, water, 1,022; grade	63·6	1024
Slough, water, 1,043; grade	66·0	1045
Boyne River, low water, 1,034; grade	68·9	1047
Norcross (*b*) Beach of Lake Agassiz, crest, 1,167; grade	75·2	1162
(The descent from the crest eastward is 15 feet, and westward 10 feet.)		
Norcross (*a*) Beach, crest, 1,195; grade	75·7	1191
Herman (*dd*) Beach, crest, 1,211; grade	76·0	1206
(The descent from the crest eastward is 15 feet, and westward 7 feet.)		
Summit on the Herman (*d*) Beach, natural surface and grade	76·2	1217
Little Boyne River, low water, 1,169; grade	77·3	1209
Treherne	77·6	1212
Boyne River, low water, 1,166; grade	78·4	1222
Herman (*bb*) Beach, crest, 1,252; grade	80·6	1247
(The descent from the crest, both to the east and west, is about 10 feet.)		
Summit, natural surface and grade the same, being the highest grade on this profile	84·8	1248
Holland	85·9	1237
Cypress River Station	96·0	1232
Cypress River, low water	95·7	1214
Glenboro (end of track, 1886)	105·0	1231
Summit in Sec. 4, T. 6, R. 16	.....	1489
Divide between Souris River and Pelican Lake in Lang's Valley (the channel of a glacial river that flowed southeast from Lake Souris to the Pembina River)	.....	1364
Prairie west of Lang's Valley	.....	1524
Souris River at Souris City	.....	1164
Souris River at Milford	.....	1114

CANADIAN PACIFIC RAILWAY SYSTEM—Continued.

WEST SELKIRK BRANCH.

(From profile in the office of P. A. Peterson, engineer, Montreal.)

[NOTE.—The two following branches of the Canadian Pacific Railway, run northward from Winnipeg on the west side of the Red River, receive an additi 24 feet, like the main line from Winnipeg west.]

	From Winnipeg.	Above th
	Miles.	*Feet.*
Winnipeg	0·0	
Junction with main line	1·5	
(This branch is very nearly level, ranging from 760 to 750 feet, between Winnipeg and Lower Fort Garry (also called the "Stone Fort.")		
Lower Fort Garry	19·5	
West Selkirk	23·5	
End of the "river track"	24·1	
Red River, ordinary stages of low and high water	24·1	71

STONEWALL BRANCH.

[From R. M. Pratt, engineer, Winnipeg.]

Winnipeg	0·0	
Air Line Junction, with main line	1·9	
Stony Mountain Station	13·3	
Stonewall	19·8	

WINNIPEG AND HUDSON BAY RAILWAY.

[From Collingwood Schreiber, engineer of government railways, Ottawa; with addition of 2 (page 40).]

Winnipeg	0·0	
Junction with the Canadian Pacific Railway	4·7	
Burnside Beach of Lake Agassiz about 3 miles south of Shoal Lake, crest and grade the same	31·0	
Lowest natural surface crossed by this railway besides Shoal Lake, 852; grade	38·2	
Shoal Lake, 5 to 15 feet deep, surface at ordinary low stage, 850; low and high water		84

MANITOBA AND NORTHWESTERN RAILWAY.

[From profiles in the office of George H. Webster, engineer, Portage la Prairie.]

These profiles are referred to the Canadian Pacific Railway station at Porta Prairie, which is called 100 feet. The original figures accordingly receive h uniform addition of 754 feet to refer them to mean sea level.

MAIN LINE.

	From Portage la Prairie.	Above th
Portage la Prairie, Canadian Pacific Railway station, 1,478·8 miles west from Montreal, 56 miles west from Winnipeg	*Miles.* 0·0	*Feet*
Same, Manitoba and Northwestern Railway station	0·0	

MANITOBA AND NORTHWESTERN RAILWAY—Continued.

MAIN LINE—Continued.

	From Portage la Prairie.	Above the sea.
	Miles.	*Feet.*
Channel by which the Assiniboine River overflowed into Lake Manitoba, May 3–15, 1882, bed, 850; grade	2·9	859
Macdonald	9·8	857
Westbourne	16·9	831
White Mud River, first crossing, bed, 812; grade	17·4	831
Burnside Beach of Lake Agassiz, crest, 860–862; grade at switch of spur track to gravel pit	21·8	860
Woodside	26·8	858
White Mud River, second crossing, bed, 849; grade	27·3	859
Summit, grade (1 foot above natural surface)	33·2	878
Depression, filling 3 feet; grade	34·0	876
Gladstone Beach, natural surface at crest, 878; grade	34·3	880
Verge of plain of Gladstone, natural surface, 882; grade	34·5	884
Gladstone, section house and tank; grade	34·7	884
Same, passenger station	34·9	883
White Mud River, third crossing, bed, 871; grade	35·7	889
Gopher Creek, bed, 876; grade	36·5	888
Secondary Emerado Beach, 40 rods wide, crest, 916: grade. (Depression west of this, 914 feet, marking the beginning of a more rapid ascent westward.)	39·1	917
Emerado Beach, about 30 rods wide, crest, 927–929, wind-blown in hollows 1 to 2 feet below crest. (Depression west of this, 925.)	39·9	927–929
Third Blanchard Beach, crest and grade alike. (This beach ridge is 30 rods wide, with descent of 5 feet both to the east and west from its crest.)	42·4	969
Midway	43·3	975
Second Blanchard Beach, crest, 979; grade. (This deposit is almost flat, not having the usual ridged form. It is nearly a quarter of a mile wide, and is bordered on the west by a depression of 2 feet, to 977.)	43·9–44·1	980
First or Upper Blanchard Beach, another tract nearly like the last, natural surface, 994; grade	45·3 –45·4	995
Depression, natural surface, 991; grade	45·5	993
Level grade (½ to 2 feet above the natural surface)	45·7 –46·1	1004
Lower McCauleyville Beach, crest and grade alike. (Depression west of this, 1,014.)	46·4	1016
Middle McCauleyville Beach, crest, 1,029; grade. (Descent of 3 and 5 feet, respectively, to the west and east from the crest.)	47·0	1025
Stream, bed, 1,018; grade	47·1	1027
Upper McCauleyville Beach, crest, 1,039; grade. (Descent of 4 and 6 feet, respectively, to the west and east from the crest.)	47·6	1035
Lower Campbell Beach, crest, 1,061; grade. (This beach ridge is 20 rods wide, with descent of 8 feet east and 5 feet west.)	48·2	1056
Slight beach mark, natural surface	48·6	1070
Beginning of nearly level grade on the east margin of the Arden beach ridge (the Beautiful Plain), 2 feet above the natural surface	48·7	1079
Arden	51·6	1086
Upper Campbell Beach ridge, excavated for ballast, crest, 1,069; grade	51·8	1084
Snake Creek, bed, 1,061; grade	52·0	1079
Lower Tintah Beach ridge, crest and grade alike. (This has a width of about 35 rods, with a descent of 4 feet to the east and 3 feet to the west.)	55·4	1111
Beach ridge, associated with the preceding, crest, 1,115; grade	55·7	1116

MANITOBA AND NORTHWESTERN RAILWAY—Continued.

MAIN LINE—Continued.

	From Portage la Prairie.	Above the
	Miles.	*Feet.*
Dune crossed on steep grade, crest, 1,133; grade	56·9	1
(Dunes 3 to 5 feet high occur at 57·15, 57·2, and 57·3 miles, with crest and grade alike in each, respectively 1,150, 1,152½, and 1,154 feet.)		
Level grade (0 to 7 feet above the natural surface)	57·3 –57·7	1
Upper Tintah Beach, crest, 1,158; grade	57·8	1
(This has a descent of 11 feet in 50 rods east, and 3 feet in 6 rods west.)		
Nearly level natural surface, 1,174–1,172; grade	58·1 –58·8	1174–1
Ridge of dune sand, crest, 1,177; grade	58·9	1
(This has a descent of 5 feet to the east and 3 feet to the west.)		
Ridge of dune sand, crest, 1,179; grade	59·3	1
(This likewise has a descent of 5 feet to the east and 3 feet to the west.)		
(Dunes at the level of the Lower Norcross Beach occur at 60·1, 60·2, 60·25, and 60·3 miles, with their crests successively at 1,192, 1,192½, 1,192½, and 1,193½ feet. The hollows are 2, 4, and 5 feet deep in order from east to west, i. e., at 1,190, 1,188½, and 1,187½ feet.)		
Grade here	60·1 –60·5	1
(From the dunes at 58·9 miles and 59·3 miles to 60·5 miles the surface is wind-blown sand with hollows 2 to 4 feet deep. The railway bed formed of this sand is somewhat insecure, because of its liability to be channeled by the wind.)		
Neepawa	61·0	1
Upper Norcross Beach deposits, crests successively 1,223½, 1,225, and 1,225; grade	61·45–61·6	1227–1
(The descent westward from each crest is only 1 foot.)		
Eroded escarpment, base, 1,225; crest, 1,240; grade	61·6 –61·67	1232–1
Herman (*bb*) Beach ridge, crest, 1,304; grade	64·0	1
(This ridge has a width of 40 rods, with descent of 7 feet both to the east and west from its crest. It is found to consist of sand and gravel suitable for ballast, nearly like that of the Arden ridge, and has been purchased by the railway company for this use.)		
Herman (*b*) Beach ridge, crest, 1,323; grade	64·7	1
(This ridge descends 7 feet from crest to base in 15 rods, the amount of descent and length of slope being nearly alike on the east and west.)		
Stony Creek, bed, 1,359; grade	66·3	1
Bridge Creek Station	70·3	1
Summit, grade (2 feet above natural surface)	76·0	1
Little Saskatchewan River, bed, 1,654; grade	78·4	1
Minnedosa, junction of Rapid City Branch	78·5	1
Summit, grade (2 feet above natural surface)	83·0	1
Depression, filling 8 feet; grade	83·9	1
Summit, grade (3 feet above natural surface)	87·0	1
Basswood	88·5	1
Outlet from Basswood Lake, bed, 1,932; grade	88·6	1
Summit, highest grade on this railway	92·8	1
Newdale	96·8	1
Grade and natural surface	100·0	1
Grade and natural surface	103·0	1
Strathclair	106·1	1
Salt Lake, bed, 1,855; water, 1,860; grade	108·3	1
Summit, cutting 4 feet; grade	109·0	1
Shoal Lake Station	114·9	1
Oak River, bed, 1,791; water, 1,794; grade	115·0	1

MANITOBA AND NORTHWESTERN RAILWAY—Continued.

MAIN LINE—Continued.

	From Portage la Prairie.	Above the sea.
	Miles.	*Feet.*
Shoal Lake, about a third of a mile south; water, approximately	115·0	1793
Summit, cutting 2 feet; grade	117·0	1830
Kelloe	123·2	1814
Solsgirth	129·8	1789
Grade (8 feet above natural surface)	132·0	1697
Ravine, bottom, 1,596; grade	132·8	1648
Birdtail Creek, bed, 1,538; water, 1,540; grade	134·5	1558
Summit, grade (1 foot above natural surface)	137·0	1704
Birtle	137·6	1703
Summit, cutting 1 foot; grade	138·6	1706
Stony Creek, bed, 1,683; grade	139·0	1701
Summit, grade (1 foot above natural surface)	144·0	1747
Foxwarren	145·2	1742
Summit, grade	149·0	1772
Silver Creek, bed, 1,631; water, 1,632; grade	153·9	1704
Binscarth, junction of Shell River Branch	154·9	1713
Two miles northwest of same, natural surface and grade	157·0	1654
Three miles farther northwest, natural surface, 1,515; grade	160·0	1521
Johnson's Creek, bed, 1,350; grade	161·8	1408
Old channel of Assiniboine River, bed, 1,317; stagnant water, 1,319; grade	162·7	1349
Assiniboine River, bed, 1,309; water, 1,314; grade	162·9	1342
One mile northwest of same, natural surface, 1,405; grade	164·0	1408
Two miles farther northwest, natural surface and grade	166·0	1533
Harrowby	167·6	1593
Grade and natural surface	173·0	1638
Langenburg	180·1	1681

RAPID CITY BRANCH (SASKATCHEWAN AND WESTERN RAILWAY).

Minnedosa, junction with main line	78·5	1670
Little Saskatchewan River, first crossing, bed, 1,643; water, 1,645; grade	80·2	1658
Riverdale	87·1	1636
Little Saskatchewan River, second crossing, bed, 1,569; water, 1,570; grade	92·4	1579
Rapid City	93·9	1579
A survey from Rapid City westward supplies the following:		
Surface, SE. ¼ of Sec. 19, T. 13, R. 20	101·5	1701
Surface, W. ½ of Sec. 16, T. 13, R. 21	105·5	1734
Oak River, Sec. 23, T. 13, R. 22, water, 1,668; proposed grade	109·2	1703
Surface on line between Secs. 28 and 33, T. 14, R. 25	132·0	1688
Surface, SW. ¼ of Sec. 6, T. 15, R. 25	135·5	1623

SHELL RIVER BRANCH.

Binscarth, junction with main line	154·9	1713
Four miles north of same, grade and natural surface	158·9	1791
Four miles farther north, grade (3 feet above natural surface)	162·9	1797
Russell	166·2	1830

MANITOBA AND NORTHWESTERN RAILWAY—Continued.

LINE SURVEYED WEST FROM LANGENBURG TO THE SOUTH SIDE OF THE BEAVER HILLS.

	From Portage la Prairie.	Above the sea.
	Miles.	*Feet.*
Red Deer Horn Creek, bed	185·0	1721
Surface	188·0	1729
Surface	195·0	1726
Big Cut Arm Creek, bed	198·5	1651
Surface	203·0	1720
Surface	210·0	1709
Crescent and Leech Lakes, a few miles north of this line, approximately		1679
Surface	220·0	1763
Surface	230·0	1816
Surface	234·0	1863
Ravine, bottom	236·0	1882
Surface, end of survey	237·5	1919
This line ends in the west part of T. 23, R. 7 W. from the second initial meridian, between the Beaver Hills on the north and the Pheasant Hills on the south, and about 15 miles east of the File Hills.		

LINE SURVEYED NORTHWEST FROM LANGENBURG, PASSING NORTHEAST AND NORTH OF THE BEAVER HILLS.

Summit	194·0	1774
Surface	212·0	1721
Armstrong's Coulée, first crossing, bed	213·9	1686
Same, second crossing, bed	217·4	1652
Yorkton	222·5	1633
Mill Creek (South Branch of White Sand River), bed	223·3	1585
Surface	226·0	1620
Summit	231·0	1697
Creek, bed	233·1	1654
Big Bone Creek (or Little White Sand River), bed	233·5	1651
Surface	238·0	1690
Owl Creek, bed	240·2	1683
Surface	243·0	1709
Clair Creek, bed	244·5	1691
Small Lake	245·7	1711
Surface	252·0	1747
Chippewa Creek, bed	253·8	1736
Surface	256·5	1770
Fern Creek, bed	258·3	1747
Surface	260·0	1781
Bear Creek, bed	262·7	1762
Spring Creek, bed	265·3	1785
Surface	270·0	1820
Water course, bed	272·5	1813
Surface	273·0	1825
Along its last 40 miles this line lies from 2 to 7 miles southwest of White Sand River. It terminates near the north side of T. 30, R. 10 W. from the second initial meridian, a few miles north of the Beaver Hills and about 25 miles east of the Big Touchwood Hills.		

NORTHWEST COAL AND NAVIGATION COMPANY'S RAILWAY.

[From Dr. George M. Dawson, of the Geological and Natural History Survey of Canada.]

	From Dunmore.	Above the sea.
	Miles.	*Feet.*
Dunmore, junction with Canadian Pacific Railway, 652·8 miles from Winnipeg	0	2405
Bull's Head Creek, grade on bridge	2	2314
Seven Persons River, grade on bridge	16	2446
Crossing the west line of T. 11, R. 8, a summit of grade	27	2772
Entering the northeast corner of T. 10, R. 11	40	2592
Depression, grade	49	2562
Crossing the west line of—		
T. 10, R. 12	53	2614
T. 10, R. 14	65	2609
T. 9, R. 16	78	2677
T. 9, R. 17	84	2707
T. 9, R. 18	90	2763
Depression, grade	91	2751
Crossing the west line of T. 9, R. 19	96·5	2806
Same, T. 9, R. 20	103	2877
Summit of grade	106	2999
Lethbridge	109	2954
This elevation proves the approximate correctness of that barometrically determined by Dr. Dawson, before this railway was built, for the Belly River (2,717 feet) at the "Coal Banks," about a mile southwest of Lethbridge. The general surface of the country here is 250 to 300 feet above the river.		

REGINA AND LONG LAKE RAILWAY.

[From R. M. Pratt, engineer, Winnipeg.]

	From Regina.	Above the sea.
	Miles.	*Feet.*
Regina, junction with the Canadian Pacific Railway	0·0	1885
Qu'Appelle River, low water, 1,795; grade	21·4	1609
End of track	22·2	1606
Arm of Long Lake here, in Sec. 23, T. 20, R. 21, water	22·2	1598
Longlaketon, at the southeast end of the main lake, is about 3 miles farther northwest.		

ST. PAUL AND DULUTH RAILROAD.

[From profiles in the office of H. A. Swenson and C. A. F. Morris, engineers, St. Paul, showing changes made in 1887 in grades along the whole line and in the construction of a shorter line with less steep grades between the St. Louis River and Oneota Junction.]

The profile from new leveling in 1887, which is here followed, receives an addition of 407 feet from St. Paul to the Northern Pacific Junction, where it gives an elevation 5 feet less than the profile thence to Deluth. The latter portion receives an addition of 402 feet. The datum is Lake Superior, mean, 200; its true elevation being 602 feet, according to the United States Lake Survey. Without adjustment, excepting that indicated at Northern Pacific Junction, this line gives the elevation of the Mississippi River, low water, at St. Paul, 683 feet, which is a half foot higher than its determination by surveys from Lake Michigan by way of Winona. It agrees exactly or closely with connecting railways at St. Paul, Minneapolis, Gladstone, White Bear, and Hinckley; and its branches to Stillwater, Taylor's Falls, and Grantsburgh agree with elevations of the St. Croix River determined by United States engineers.

ST. PAUL AND DULUTH RAILROAD—Continued.

MAIN LINE.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, extreme low and high water in the Mississippi River	0·0	683–702
St. Paul, union depot	0·0	703
East Seventh Street, junction to terminal freight yard	0·8	734
Crossing beneath the Chicago, St. Paul, Minneapolis and Omaha Railway; St. Paul and Duluth grade	1·6	809
Phalen's Creek:		
First crossing, water, 805; grade	1·65	811
Second crossing, water, 809; grade	1·7	813
Third crossing, water, 816; grade	1·9	820
Fourth crossing, water, 839; grade	2·6	853
Claymont (at St. Paul Harvester Works)	2·9	865
Phalen's Creek, fifth crossing, water, 856; grade	3·1	868
Lake Phalen, water, 859; grade	3·7	862
Gladstone	4·9	898
Junction with the Wisconsin Central Railroad	5·1	899
Summit, natural surface	8·7	976
Same, grade	9·0	937
Minneapolis and Duluth Junction	10·0	927
White Bear	11·4	938
White Bear Lake, low and high water	11·4	923–926
Junction of the Stillwater Branch	11·6	938
Crossing the Minneapolis, Sault Ste. Marie and Atlantic Railway	12·5	929
Bald Eagle	12·9	928
Bald Eagle Lake, water	12·9	908
Beaver Creek, water, 923; grade	16·4	934
Centerville	16·7	933
Beaver Dam pile-bridge, water, 920; grade	17·5	932
Rice Creek, water, 915; grade	20·2	933
Summit, cutting 9 feet; grade	21·5	951
Forest Lake Station	25·0	912
Forest Lake, water	25·0	900
Wyoming, junction of the Taylor's Falls Branch	29·2	900
South Branch of Sunrise River, water, 876; grade	29·5	896
Middle Branch of Sunrise River, water, 878; grade	33·2	893
Stacy	33·4	896
North Branch Station	41·3	896
North Branch of Sunrise River, water, 865; grade	41·6	896
Harris	46·5	897
Goose Creek, water, 870; grade	46·7	899
Spooner's Spur	51·4	917
Junction of the Grantsburg Branch	53·1	917
Rush Creek, water, 895; grade	53·1	917
Rush City	53·3	917
Balsam Creek, water, 926; grade	56.5	934
Long's Spur	57·3	943
South Branch of Rock Creek, water, 919; grade	58·3	937
North Branch of Rock Creek, water, 925; grade	59·0	945
Dowlan's Siding	59 5	955
Summit, natural surface	60·7	986
Same, grade	60·9	975
Cut, maximum depth 33 feet, but only 300 feet long; grade	62·3	965
Fill 16 feet, opposite to Devil's Lake; grade	62·4	964
Pine City	63·2	952
Snake River, bed, 920; low and high water, 928–938; grade	63·4	950
Summit, "Brown's Hill," cutting 22 feet; grade	67·4	980
Brown's Hill Siding	69·2	975
Mission Creek, water, 960; grade	70·2	967
Mission Creek Station	73·1	995

ST. PAUL AND DULUTH RAILROAD—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Cut, maximum depth 31 feet; grade	74·2	1011
Creek, water, 1,002; grade	75·0	1017
Junction, St. Cloud and Hinckley Branch, St. Paul, Minneapolis and Manitoba Railway	76·1	1032
Hinckley	76·2	1032
Grindstone River, water, 1,010; grade	76·7	1032
Summit, grade	81·1	1117
Same, natural surface	81·2	1130
Sandstone Junction	83·6	1119
Miller	85·9	1136
Finlayson	89·4	1108
Creek, water, 1,087; grade	90·2	1095
Pine River, water, 1,024; grade	93·1	1051
Kettle River Station	94·3	1031
Kettle River, water, 1,010; grade	94·7	1029
Willow River Station	98·5	1038
Willow River, water, 1,020; grade	98·7	1037
Sturgeon Lake Siding	102·2–102·8	1067–1076
Cut, 13 feet deep; grade	103·7	1088
Summit, natural surface and grade the same	104·2	1095
Moose Horn River, water, 1,038; grade	107·7	1056
Moose Lake Station	108·8	1063
Summit, natural surface	111·8	1115
Same, grade	112·0	1108
Barnum	113·4	1100
Moose Horn River, water, 1,091; grade	113·5	1101
Cut, 16 feet deep; grade	114·1	1110
Cut, 21 feet deep; grade	117·1	1135
Mahtowa	119·5	1147
Black Hoof Summit, natural surface and grade the same, highest on this railroad	120·7	1170
Otter Creek Siding	125·2	1150
Northern Pacific Junction	131·5	1083
St. Louis River, Dalles bridge, bed, 992; low and high water, 997–1,020; grade	132·5	1044
Thomson	133·0	1055
Big Gulch, bottom of culvert, 981; grade	135·1	1095
Summit Siding	135·9–136·1	1115
(Cut here has maximum depth of 24 feet.)		
West Branch of Mission Creek, bed, 965; grade	138·3	1015
East Branch of Mission Creek, bed, 912; grade	138·7	993
Rock cut at southwest end of range of highland; grade	141·2–141·3	863–858
Siding	143·2–144·2	742–722
Oneota Junction, at west end of bridge over Kimball's Creek, water, 615; grade	146·2	629
Summit Level	146·7–147·4	637
Oneota	148·3	631
Duluth, passenger depot	152·1	607
Duluth, freight depot and elevators	152·9	607
Lake Superior, mean, 1871 to 1887	152·9	601·56
(Minnesota Point (recent beach at the head of Lake Superior), Duluth, has a width of 375 feet at the distance of 3,700 feet from the mainland on the lake side. Along this extent its elevation on the upper edge of the beach, next to the timber, varies from 6 to 11 feet above the lake; and the timbered belt of this point in some parts rises slightly higher.)		
(Rice's Point (a western beach near the preceding and parallel with it), along an extent of 2,574 feet varies in elevation from 3½ to 10 feet above Lake Superior.)		

ST. PAUL AND DULUTH RAILROAD—Continued.

MINNEAPOLIS BRANCH.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis, new St. Paul, Minneapolis and Manitoba (union) depot	0·0	810
Mississippi River, low and high water, 794–802; grade	0·5	826
East Minneapolis, Duluth depot	1·0	833
Junction, St. Paul, Minneapolis and Manitoba Railway	1·3	835
Crossing St. Paul, Minneapolis and Manitoba Railway	1·8	838
Summit, cutting 7 feet; grade	4·4	948
Robinson Lake, water, 908; grade	6·3	916
Owassa	6·7	927
Bennett (or Reiling) Lake, water, 893; grade	7·5	895
Owassa (or Big Bass) Lake, water, 888; grade	9·4	898
Twin Lake, water, 879; grade	10·5	883
Minneapolis and Duluth Junction	14·4	927

STILLWATER BRANCH.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
White Bear Junction	11·6	938
White Bear Lake, low and high water, 923–926; grade	13·0	934
Dellwood	13·6	942
Mahtomedi (a depression of grade)	14·6	929
Lake, water, 951; grade	17·7	966
Summit, cutting 20 feet; grade	18·1	984
Brown's Creek, bed, 858; grade	21·1	867
Same, bed, 837; grade	21·6	853
Stillwater	23·3	723
Same, zero of United States engineer's gauge, Lake St. Croix	.....	666·95
Same, zero of city levels, from Lewis W. Clarke, city engineer	.....	638·70
Lake St. Croix, ordinary stage of water, 672; extreme low and high water, 667–687; grade	24·0	686

TAYLOR'S FALLS BRANCH.

Wyoming, junction with the main line	29·2	900
Summit, cutting 6 feet; grade	30·0	903
Sunrise River, water, 875; grade	31·1	880
Summit, natural surface and grade the same	33·2	922
Chisago City	35·6	917
Canal, water the same as Chisago Lake, 896; grade	35·8	917
Chisago Lake, water, 896; grade	38·0	928
Lindstrom	38·2	932
Summit, natural surface and grade	38·7	937
Chisago Lake, water, 896; grade	39·8	901
Center City	39·9	901
Summit, cutting 4 feet; grade	42·2	946
Shafer's	43·4	937
Franconia	45·4	915
Lawrence Creek, bed, 857; water, 861; grade	45·9	901
Cuts in sandstone, top of sandstone, 856–861; grade	47·4–47·8	855–832
Cut in trap, top of trap rock, 823; grade	48·4–48·5	802–797
Taylor's Falls, passenger depot	48·7	791
Same, freight depot and yard	49·5	750
St. Croix River here, a mile north from Taylor's Falls bridge, about	49·5	710

ST. PAUL AND DULUTH RAILROAD—Continued.

GRANTSBURG BRANCH.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Junction near Rush City	53·1	917
Rush Creek, water, 841; grade	55·8	849
St. Croix River, water, 775; grade	58·1	795
Summit (at or near Benson), natural surface and grade	68·6	921
Grantsburg	69·7	895

KNIFE FALLS BRANCH.

Northern Pacific Junction	131·5	1083
St. Louis River, crest of Knife Falls, 1,167, having a perpendicular fall of 8 feet; high water on crest of falls, 1,172; grade here	136·4	1180
Knife Falls (Cloquet post-office)	137·3	1192
St. Louis River here, at head of the rapids above Knife Falls, ordinary stage, about	137·3	1175

PRELIMINARY SURVEYS.

[From preliminary surveys for the St. Paul and Duluth Railroad in 1860 and 1864, of which the field-notes were supplied by A. J. Hill, St. Paul.]

	Feet above the sea.
Goose Lake, Sec. 23, White Bear, Ramsey County	925
Lake Amelia, Sec. 35, Centerville, Anoka County	906
Middle Branch of Sunrise River, in the northeast part of Linwood, Anoka County	877
Goose Lake, Chisago County	910
Rush Lake, Chisago County	906
Rock Lake, Secs. 8 and 9, T. 38, R. 21	947
Snake River, close southwest of Pokegama Lake	929
Pokegama Creek, Sec. 15, T. 40, R. 22	1003
South Branch of Grindstone River, in the northeast part of T. 41, R. 22	1065
Willow River, Sec. 33, T. 45, R. 19	1047
Moose Lake, Secs. 26 and 35, T. 46, R. 19	1105
Pine Lakes, east part of T. 43, R. 22, head of Pine River	1075
West Branch of Kettle River, in the southeast corner of T. 46, R. 22	1232
Highest land crossed by the survey in 1860, situated in the SW. ¼ of Sec. 36, T. 47, R. 22	1356
Lake in Secs. 3 and 9, T. 48, R. 20 (close south of Island Lake on the Northern Pacific Railroad)	1296
Kettle River (15 feet wide, 4 feet deep), in the NW. ¼ of Sec. 8, T. 48, R. 19	1280
(This is ¼–1 mile south of the Northern Pacific crossing of the same stream, where its bed is at 1,287 feet.)	
Lake 4 miles east of the last, flowing northeastward to the Perch Lakes, and so tributary to the Moose River	1306
Moose River, near Norman	1275
Creek (25 feet wide, 2 feet deep), in the NE. ¼ of Sec. 11, T. 48, R. 17	1088
(This is about 1½ miles west-southwest of the Northern Pacific Junction.)	
Hay Lake	1105
Chub Lake	1111
St. Louis River (40 feet wide) below the upper falls (and east of the railroad bridge), ordinary stage	989
Same, high water	1007
(The river here flows in a perpendicular gorge, south bank, 1,008; north bank, 1,019.)	

DULUTH AND IRON RANGE RAILROAD.

[From R. H. Lee, engineer, Duluth.]

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Lake Superior, mean, 1871 to 1887	0·0	601·56
Duluth, junction with the St. Paul and Duluth Railroad	0·0	607
Chester Creek, bed, 602; grade	0·8	632
Tischer Creek, bed, 634; grade	2·6	667
Summit, cutting 4 feet; grade	3·0	686
New London	4·0	685
Lester Park	5·0	650
Lester River, bed, 604; grade	5·3	650
Summit, cutting 2 feet; grade	7·5	665
Clifton	8·0	661
Talmage River, bed, 658; grade	10·7	691
Summit, natural surface and grade	11·0	700
French River, bed, 677; grade	12·1	697
Smith's Creek bed, 650; grade	12·6	696
Summit, cutting 9 feet; grade	13·0	700
Big Sucker River, bed, 630; grade	14·8	684
Little Sucker River, bed, 612; grade	15·6	664
Lake View	16·0	661
Stony Point, cutting 9 feet; grade	16·7	671
Knife River Station, bed of river, 602; grade	18·7	620
Summit, natural surface and grade	24·5	767
Two Harbors Junction	26·1	692
Two Harbors depot, ¼ mile south from the junction	.....	634
Sibiwissa	32·0	1230
Gakadina Station, highest point on the line, cutting 26 feet; grade	38·8	1734
Little Cloquet River, bed, 1,498; grade	44·2	1521
Cloquet River Station, bed of Cloquet River, 1,477; grade	46·2	1490
Wissakode	49·5	1578
Summit, cutting 2 feet; grade	51·4	1617
Summit, cutting 29 feet; grade	52·7	1615
Outlet of Bassett Lake, bed, 1,570; grade	53·2	1587
Bassett Lake Station, cutting 19 feet; grade	55·0	1642
Whiteface River, bed, 1609; grade	55·4	1635
Summit, cutting 14 feet; grade	57·7	1693
St. Louis River Station, bed of river, 1,594; grade	62·1	1607
Partridge River, bed, 1,499; grade	68·3	1514
Okwanim	70·2	1494
Beaver Dam Creek here, bed, 1,481; grade	70·2	1494
Summit, cutting 7 feet; grade	72·2	1536
Mesaba Creek, bed, 1,479; grade	73·7	1486
Mesaba Heights Station, cutting 7 feet; grade	75·3	1604
Embarras River, bed, 1,421; grade	80·4	1440
Summit, cutting 23 feet; grade	84·9	1484
West Two Rivers, bed, 1,414; grade	89·4	1424
West Two Rivers, bed, 1,401; grade	89·7	1413
Summit, cutting 10 feet; grade	90·4	1439
East Two Rivers, bed, 1,374; grade	91·8	1384
Breitung Mine Station, Tower yard	94·0	1424
Tower, about	95·7	1400
Vermilion Lake, water	95·7	1357

WISCONSIN CENTRAL RAILROAD (THE PART IN MINNESOTA).

[From the Fifteenth Annual Report of the Geological and Natural History Survey of Minnesota, 1886. pp. 429, 430. Corrected by uniform subtraction of 39 feet, which is here made, to agree with the St. Paul and Duluth Railroad, and with elevations of the St. Croix River determined by United States engineers.]

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, union depot	0·0	703
Junction with the St. Paul and Duluth Railroad, Gladstone	5·1	899
Castle	8·6	986
Long Lake, water, 936; grade	10·3	951
Four Lakes Station	10·9	966
Summit, cutting 11 feet; grade	12·2	1035
Crossing the Stillwater Branch, St. Paul and Duluth Railroad	14·5	978
Carnelian Lake, water, 873; grade	20·9	881
Arcola	23·1	878
St. Croix River, bed, 666; ordinary low stage of water, 676; extreme low and high water, 670–689; grade	25·5	755

CHICAGO, BURLINGTON AND NORTHERN RAILROAD (THE PART IN MINNESOTA).

[From profile in the office of Charles C. Upham, engineer, St. Paul. Agreeing with the elevations of the Mississippi River at St. Paul and Hastings, and of the St. Croix River at Prescott, determined by United States engineers.]

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis, union depot	0·0	810
St. Paul, union depot	10·7	703
Mississippi River here, low and high water	10·7	683–702
Dayton Bluff	12·4	707
Newport	18·8	748
Crossing the River division, Chicago, Milwaukee and St. Paul Railway	18·9	748
Summit, natural surface and grade	21·1	756
Curry	26·5	696
Mississippi River, beside this railroad about 1¼ miles above Hastings, ordinary low stage of water, 674; extreme low and high water	29·5	671·6–690·7
Crossing the River division, Chicago, Milwaukee and St. Paul Railway	30·6	692
St. Croix Junction	30·7	692
Crossing the Stillwater Branch, Chicago, Milwaukee and St. Paul Railway	30·9	695
Point Douglas	32·7	708
St. Croix River, bed, 650; ordinary stage of water, 672; extreme low and high water, 667–687; grade	33·4	700
Prescott	33·6	700

MINNEAPOLIS, SAULT STE. MARIE AND ATLANTIC RAILWAY.

[From W. W. Rich, engineer, Minneapolis.]

Referring this profile to sea level by the elevation of Lake Superior, 602 feet, it is found to be 3 feet too low at Minneapolis. From Minneapolis to the third crossing of the South Fork of Beaver Brook, at 71·8 miles, the elevations here given accord with the accepted elevations of St. Paul and Minneapolis; and thence eastward, namely, from Turtle Lake Station (which agrees within 1 foot with the Chicago, St. Paul, Minneapolis and Omaha Railway) to Sault Ste. Marie, they accord with that of Lake Superior.

MINNEAPOLIS, SAULT STE. MARIE AND ATLANTIC RAILWAY—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis, union depot	0·0	810
Same, depot of this railway, Fourth avenue and Second street northwest	0·5	826
Mississippi River at bridge of St. Paul and Northern Pacific Railroad in the north part of Minneapolis, used also by this railway, river bed, 783; low and high water, 794–803; grade	1·8	825
Crossing the St. Paul, Minneapolis and Manitoba Railway	3·2	847
Minneapolis shops	3·7	847
Sandy Lake, water, 838; grade	3·9	851
Summit on line between Anoka and Ramsey Counties, cutting 8 feet; grade	5·9	950
Wilson	6·7	933
New Brighton	8·1	920
Maryland Park	9·6	926
Island Lake, water, 942; grade	10·7	950
Vadnais Park	12·7	898
Summit, cutting 13 feet; grade	15·4	946
Outlet of White Bear Lake, water (5 feet below the lake), 919; grade	18·4	928
Bald Eagle Junction, at crossing of the St. Paul and Duluth Railroad	18·5	929
Garden Place	19·1	932
Pine Lake, water, 943; grade	21·0	948
Summit, filling 5 feet; grade	23·2	1011
Withrow	24·1	980
Carnelian Creek, bed, 930; grade	27·9	951
Maple Island	28·6	961
Summit, grade	29·3	978
Creek, bed, 924; grade	30·0	955
Marine	33·6	927
Otisville	37·2	788
St. Croix River, bed, 670; low water, 680; extreme high water, 697; grade	39·3	706
Bridge near Buttermilk Falls, bed of creek, 683; grade	40·9	728
Osceola	43·2	809
Godfrey Junction, St. Croix Falls Branch	48·1	950
Switch of the St. Croix Falls Branch	48·2	954
On this branch:		
Summit, grade	50·4	1028
St. Croix Falls	52·2	920
On the main line east from Godfrey Junction:		
Summit, cutting 14 feet; grade	49·4	984
Nye	52·6	955
Sucker Creek, bed, 1,010; water, 1,012; grade	58·8	1040
Deronda	59·9	1066
Bear Trap Lake, water, 1,038; grade	60·6	1056
Amery	63·2	1070
Apple River, bed 1,051; low and high water, 1,055–1063; grade	63·4	1070
Beaver Brook, first crossing, water, 1,067; grade	65·1	1085
East Lincoln	65·6	1100
Beaver Brook, second crossing, water, 1,083; grade	66·3	1103
Gregory (a summit of grade)	68·2	1132
South Fork of Beaver Brook, first crossing, water, 1,115; grade	69·9	1122
Same, second crossing, water, 1,132; grade	71·0	1148
Same, third crossing, water, 1,140; grade	71·8	1151
Turtle Lake Station (a summit of grade), at crossing of the Chicago, St. Paul, Minneapolis and Omaha Railway	76·0	1258
Lightning Creek, bed, 1,145; water, 1,147; top of bank, 1,172; grade	82·1	1169
Hay River, bed, 1,136; water, 1,139; bank, 1,187 grade	83·1	1179

MINNEAPOLIS, SAULT STE. MARIE AND ATLANTIC RAILWAY—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Barron	91·4	1111
Yellow River, bed, 1,082; low and high water, 1,085–1,096; top of bank and grade	91·9	1104
Menominee River, bed, 1,065; water, 1,069; grade	94·8	1095
Pokegama Creek, bed, 1,052; top of bluff, 1,096; grade	100·4	1077
Canton	101·0	1101
Summit, cutting 15 feet; grade	110·7	1303
Weyerhaeuser	114·4	1297
Bruce	121·6	1098
Chippewa River, bed, 1,057; low and high water, 1,062–1,076; top of bank, 1070; grade	122·7	1082
Flambeau Falls	130·0	1142
Flambeau River, bed, 1,082; low water, 1,092–1,097; west bank, 1,123; east bank, 1,150; grade	131·2	1123
Deer Tail	135·9	1221
Main Creek, bed, 1,270; water, 1,272; bank 1,300; grade	144·5	1297
Ingram	144·8	1301
Hawkins	149·4	1365
Willard	159·0	1493
North Branch of Jump River, bed, 1,420; water, 1,422; top of bank, 1,470; grade	161·5	1449
Prentice	170·9	1551
Summit, filling 2 feet; grade (highest on this railway)	179·7	1696
Bradley	197·8	1473
Tomahawk River, bed, 1,440; low and high water, 1,442–1,448; bank, 1,470; grade	198·2	1467
Big Rice Creek, bed, 1,444; water, 1,450; bank, 1,477; grade	201·7	1468
Wisconsin River, bed, 1,525; water, 1,528; bank, 1,545; grade	216·7	1552
Rhinelander	217·0	1555
Pennington	227·6	1635
Gagen	231·4	1545
Summit, cutting 10 feet; grade	235·2	1691
Peshtigo River, first crossing, bed, 1,618; water, 1,620; bank, 1,646; grade	242·8	1640
Same, second crossing, bed, 1,540; water, 1,542; bank, 1,546; grade	247·2	1552
Armstrong Creek Station	265·8	1427
Pike River, bed, 1,209; water, 1,212; bank, 1,262; grade	275·6	1252
Pike River Station	276·4	1222
Pembine	289·7	968
South Branch of Pembine River, bed, 808; water, 810; grade	295·1	827
Van Horne	296·4	807
North Branch of Pembine River, bed, 797; water, 799; grade	297·4	824
Menominee River, bed, 787; low and high water, 791–797; grade	301·9	816
Menominee River Station	302·2	816
Meyer	305·7	920
Hermansville	311·0	887
Cedar River, bed, 850; low and high water, 852–856; grade	314·7	861
Springer	314·9	862
Eustis	325·3	816
Ford River, bed, 695; low and high water, 697–704; grade	330·5	716
Newhall	330·9	709
Escanaba River, bed, 587; low and high water, 596–606; grade	338·9	636
Flat Rock	339·3	629
Gladstone	342·8	612

MINNEAPOLIS, SAULT STE. MARIE AND ATLANTIC RAILWAY—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Water in Hammer's Slough, near its outlet to Little Bay de Noc	343·8	584
Masonville	348·0	593
White Fish River, bed, 577; water, 583; grade	350·1	596
Ogontz River, bed, 607; water, 609; grade	359·0	617
Ogontz	359·5	620
Sturgeon River, bed, 596; water, 603; grade	362·7	617
Sturgeon River Station	363·1	623
Van Winkle	369·3	592
Fishdam River, bed, 583; low and high water, 586-590; grade	369·7	595
Cook's Mill	375·1	702
Delta Junction	380·7	667
South Manistique	384·8	596
Manistique	386·7	613
Manistique River, bed, 598; low and high water, 605–609; grade	387·0	616
Gulliver Lake Station	398·0	626
McDonald Lake Station	400·7	622
Pike Lake Station	411·1	749
Scott's Point Station (a summit of grade)	414·5	772
Kennedy	422·1	675
Mille Coquins River, bed, 611; low and high water, 615–621; grade	424·3	629
Mille Coquins Station	425·0	632
Naubinway Junction	428·9	725
Gilchrist	431·6	779
Black River, bed, 768; water, 770; grade	432·9	784
Summit, cutting 6 feet; grade	438·1	886
Hall's Siding	441·6	864
Trout Lake Station	449·8	836
Alexander	458·2	815
Pine River, bed, 621; water, 625; grade	469·2	678
North Branch of Pine River, bed, 623; water, 629; grade	470·4	682
Pine River Station	470·6	683
Gravel Pit, cutting 14 feet; grade	475·8	753
Dafter	483·3	695
Leland	487·4	656
Sault Ste. Marie, water in canal, level from Lake Superior	494·1	602

MINNEAPOLIS AND PACIFIC RAILWAY.

[From profile in the office of W. W. Rich, engineer, Minneapolis. Referred to sea level at Minneapolis, and found to agree exactly or closely with the numerous intersecting railways along its whole extent.]

Minneapolis, union depot	0·0	810
Same, depot of this and the Minneapolis, Sault Ste. Marie and Atlantic Railways	0·5	826
Shingle Creek, bed, 815; water in mill pond, 827; grade	3·8	832
Camden Place	3·8	832
Crossing the St. Paul, Minneapolis and Manitoba Railway	7·3	872
Crystal	7·7	877
Staffordsville	11·5	927
Summit, natural surface and grade	14·2	1009
Hamel	16·0	986
Loretto	21·7	995
Summit, cutting 18 feet; grade	23·6	1011
Marmion	27·9	918
South Fork of Crow River, bed, 898; water, 903; grade	28·1	914
North Fork of Crow River, bed, 896; water, 902; grade	29·2	913

MINNEAPOLIS AND PACIFIC RAILWAY—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Buffalo	37·1	981
Trestle bridge near Lake Ramsey, 38 feet high; grade	44·3	1034
Maple Lake Station	45·0	1052
Annandale	51·2	1066
South Haven	56·1	1102
Clearwater River, bed, 1,015; grade	58·2	1080
Kimball Prairie	61·4	1138
Summit, cutting 5 feet; grade	64·4	1190
Watkins	66·8	1162
Summit, cutting 6 feet; grade	69·2	1179
Depression, grade	71·5–72·1	1107
Eden Valley	73·6	1123
Summit, grade	77·4	1217
North Fork of Crow River, bed, 1,118; grade	79·3	1164
Paynesville	82·8	1172
North Fork of Crow River, bed, 1,142; grade	83·1	1172
Crossing the St. Paul, Minneapolis and Manitoba Railway	84·6	1184
Lintonville	89·9	1220
North Fork of Crow River, bed, 1,207; grade	90·8	1218
Belgrade	98·1	1273
Brooten	104·8	1314
Thorson (a summit of grade)	112·6	1334
Depression, grade	113·4	1321
East Branch of Chippewa River, bed, 1,307; grade	115·0	1339
Glenwood	120·5	1390
Crossing the Little Falls and Dakota (Northern Pacific) Railroad	121·8	1415
Lowry	129·5	1368
Farwell	135·2	1339
Kensington (a summit of grade)	139·4	1318
Chippewa River, bed, 1,184; grade	144·0	1202
Hoffman	145·7	1246
Water course tributary to the Pomme de Terre River, bed, 1,174; grade	150·5	1230
Pomme de Terre River, bed, 1,145; water, 1,147; grade	152·9	1163
Barrett	153·7	1165
Summit, natural surface and grade	156·2	1227
Crossing the St. Paul, Minneapolis and Manitoba Railway	159·5	1201
Elbow Lake Station	160·4	1210
Wendell	167·2	1148
Herman shore of Lake Agassiz, crest of escarpment of till, 1,089; grade	170·1	1081
Same, ridge of beach gravel and sand, crest, 1,082; grade. (Descent eastward from this beach ridge, 7 feet; westward, 6 feet in 15 rods, then nearly level 8 rods, followed by a descent of 16 feet in 18 rods, to 1,060 feet.)	170·3	1073
Norcross Beach of Lake Agassiz, crest, 1,049; grade	171·3	1048
Tintah Beaches, crests (inconspicuous)	176·0–176·5	1012–1010
Nash	177·1	1000
Crossing the Breckenridge line of the St. Paul, Minneapolis and Manitoba Railway	179·0	991
Elliott	180·4	991
South Branch of Rabbit River, bed, 976; grade	180·9	991
Tenney	184·2	990
Campbell Beach deposits of Lake Agassiz, crests (inconspicuous)	186·9–187·5	983–980
Bois des Sioux River, bed, 963; grade	189·4	973
Campbell Beaches, crests (inconspicuous), 979–984; grade	190·9–191·4	981–985
Fairmount	191·4	985
Crossing the Fargo and Southern (Chicago, Milwaukee and St. Paul) Railway	191·7	985

MINNEAPOLIS AND PACIFIC RAILWAY—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Beach, crest, 993; grade	195·1	992
(Descent eastward from the crest, 5 feet in 25 rods; westward, 5 feet in 15 rods.)		
Oswald	197·5	989
Small dunes, crests, 995–997; grade	199·8–200·1	997
Hankinson	205·8	1070
Milnor Beaches of Lake Agassiz (inconspicuous), crests and grade the same	207·0–207·3	1084–1085
Crossing the St. Paul, Minneapolis and Manitoba Railway	208·3	1089
Stiles	213·0	1131
Summit, cutting 7 feet; grade	214·5	1137
Lidgerwood	217·9	1092
Alicia	223·7	1157
Grass Creek, bed, 1,118; grade	228·0	1130
Ransom	229·2	1131
Wild Rice River, bed, 1,112; water, 1,117; grade	229·5	1127
Perry	234·9	1205
Forman	240·9	1251
Towanda (a summit of grade)	246·3	1318
Crossing the Chicago, Milwaukee and St. Paul Railway.	248·0	1298
Summit, grade (2 feet above the natural surface, which is fine sand in dunes 2 to 3 feet high)	248·9	1322
Nicholson	252·2	1309
Summit, grade (1 foot below the natural surface, which is clayey loam)	253·8	1344
Babcock	258·3	1324
Summit at a pass through a belt of morainic hills, cutting 4 feet; grade	261·6	1343
Oakes	263·7	1322
Crossing the Chicago and Northwestern Railway	263·9	1321
James River, about 100 feet wide, with no perceptible current, bed (clay), 1,286; low and high water, 1,289–1,295; grade	264·9	1298
Clement	271·5	1394
Fullerton	280·6	1442
Maple River, bed, 1,420; low and high water, 1,421–1,425; grade	284·4	1435
Boynton	287·4	1497
Crossing the Chicago, Milwaukee and St. Paul Railway near Monango	288·4	1505
South Fork of Maple River, bed, 1,475; water, 1,478; grade	288·6	1501

GREAT NORTHERN, (formerly ST. PAUL, MINNEAPOLIS AND MANITOBA) RAILWAY SYSTEM.[1]

[From profiles in the office of N. D. Miller, engineer, St. Paul.]

ST. PAUL TO MINNEAPOLIS.

[Referred to sea level by the elevation of the Mississippi River at St. Paul, determined by United States engineers.]

	From St. Paul.	Above the sea.
	Miles.	*Feet*
St. Paul, extreme low and high water of the Mississippi River	0·0	683–702
St. Paul, union depot	0·0	703
Under the Mississippi Street Bridge	1·4	797
Under the Como Avenue Bridge	2·8	857

[1] The name of this railroad system was changed in 1890.

GREAT NORTHERN RAILWAY SYSTEM—Continued.

ST. PAUL TO MINNEAPOLIS—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Como	2·9	858
Hamline (a summit of grade)	5·0	926
Highest natural surface cut at 5·1, 5·4, and 5·8 miles, in each place	5·1–5·4–5·8	938
St. Anthony Park	6·9	878
Under the University Avenue Bridge	8·7	813
East Minneapolis	9·4	803
Stone arch bridge, grade	9·5–9·8	803
Tail-race from Pillsbury A mill, under east end of this bridge, water	9·5	739
Mississippi River, main stream under this bridge	9·6–9.75	743
Same, crest of St. Anthony's Falls, under west end of this bridge, ordinary stage of water held by dams, 794; highest stage of flowage by dams, 796; highest stage of floods, 802	9·9	794–802
Limestone ledge under west end of bridge, 15 feet thick, brink of original fall and foundation of dam	9·85	765–780
(This coincides with the vertical fall, 15 or 16 feet, before the dam was built. The fall down the "apron" of the dam is about 30 feet, 794–764.)		
Minneapolis depot	10·3	810
Crossing of Washington avenue (former site of depot)	10·8	830

MAIN LINE, FROM ST. PAUL, BY ST. CLOUD, FERGUS FALLS, CROOKSTON, AND GRAND FORKS, TO GREAT FALLS.

[Referred to sea level at St. Paul and Minneapolis, and found to agree exactly with connecting railways at East St. Cloud, Sauk Center, Fergus Falls, and Glyndon.]

The profile from Glyndon by Crookston to Grand Forks gives an elevation of Grand Forks 5 feet higher than the profile of the line from Breckenridge by Moorhead and Grand Forks to Neche. Leveling by United States engineers along the Red River, the connections with branches of the Canadian Pacific Railway on the international boundary at Emerson and Gretna, the survey from Carman eastward to Leach Lake, and the agreement of the Dakota division of this main line with the Jamestown and Northern Railroad at Devil's Lake, all attest the correctness of the lower elevation of Grand Forks, and show that the corresponding subtraction of 5 feet should be applied to this line at least from Carman northwestward, which is here done. Along the distance between Glyndon and Carman a subtraction of 2 feet is made in its southern half, extending to Ada, and of 3 feet thence northward.

With the accepted elevation of Grand Forks, the profile thence westward agrees exactly at Larimore with the lines from Everest and the Northern Pacific Railroad by way of Mayville and Portland; and the same elevation of Devil's Lake is obtained by leveling from this railway at Devil's Lake Station as from the Jamestown and Northern Railroad at Minnewaukon.

From Devil's Lake to Great Falls the profile consists of several series of leveling, referred to separate data. These are here reduced to sea level, and the elevation thus obtained at Great Falls is found to agree exactly with leveling to that place from the Northern Pacific Railroad at Helena.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul	0·0	703
Minneapolis	10·3	810
Fridley (formerly Manomin)	16·3	844
Rice Creek, water, 817; grade	16·5	843
Coon Creek, water, 828; grade	20·7	854
Anoka	26.6	879
Rum River, water, 841; grade	27·2	862

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Itasca	33·7	887
Elk River Station	38·5	892
Junction of the Princeton Branch	39·2	905
Elk River, water, 892; grade	43·0	906
Bailey's	43·6	917
Big Lake Station	47·6	936
Becker	55·5	973
Clear Lake Station	62·5	993
Haven	68·6	1014
East St. Cloud	73·6	1026
(From this station the St. Paul and Northern Pacific Railroad, which thus far lies side by side with this, continues north along the east side of the Mississippi to Brainerd.)		
Mississippi River, low water before the dam was built, 965; same, as now raised by the dam, 975; grade	74·2	1032
St. Cloud	74·6	1037
Same, junction with Clearwater Branch	75·0	1040
St. Cloud Junction, with Willmar Branch	76·5	1048
Sauk River, bed, 1,033; water, 1,035; grade	78·1	1050
St. Joseph	82·1	1088
Watab River, water, 1,058; grade	82·7	1075
Collegeville	84·9	1094
Summit, cutting 12 feet; grade	87·6	1150
Avon	90·3	1131
South Branch of Two Rivers, water, 1,137; grade	94·5	1144
Albany	96·3	1201
Summit, cutting 5 feet; grade	98·8	1250
Getchell Creek, water, 1,191; grade	101·3	1203
Freeport (formerly Oakes), a summit of grade	102·6	1240
Sauk River, bed, 1,168; water, 1,172; grade	106·3	1185
Melrose	108·5	1211
Sauk River, water, 1,201; grade	110·8	1213
Summit, cutting 11 feet; grade	114·2	1277
Sauk River, bed, 1,209; low and high water, 1,213–1,223; grade	115·8	1237
Sauk Center Station, and crossing the Little Falls and Dakota (Northern Pacific) Railroad	116·8	1255
Same, junction with Sauk Center and Northern Branch	117·3	1257
Hazel Creek, water, 1,236; grade	117·8	1257
Summit, grade	120·7	1330
Ashley Creek, water, 1,277; grade	121·8	1289
Silver Creek, water, 1,272; grade	122·5	1281
West Union	124·6	1337
Osakis	130·5	1343
Osakis Lake, water, about	130·5	1310
Summit, cutting 7 feet; grade	132·5	1408
Nelson	136·1	1369
Summit, cutting 7 feet; grade	137·9	1425
Outlet from Lake Victoria to Lake Geneva, water, 1,355; grade	139·1	1373
Summit, cutting 14 feet; grade	140·3	1416
Alexandria	141·5	1391
Lakes Winona and Agnes, near Alexandria, about	.....	1365
Long Prairie River, flowing southward, above its entrance into Mill Lake, water, 1,349; grade	144·5	1367
Garfield	148·3	1417
Summit, cutting 13 feet; grade, highest on this railway in Minnesota	149·8	1451
Aldrich Lake, water, 1,391; grade	151·9	1404
Brandon	154·0	1388

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Chippewa River, water, 1,339; grade	157·1	1369
Evansville, junction of branch to Tintah	159·2	1353
Summit, cutting 30 feet; grade	160·1	1378
Outlet from Lake Christina to Pelican Lake, water (approximately the same as these lakes), 1,215; grade	165·6	1227
Interlaken	165·9	1230
Ashby	168·3	1293
Summit, cutting, 10 feet; grade	168·35	1296
Pelican Creek, water, 1,238; grade	169·6	1251
Dalton (a summit of grade)	175·8	1359
Pomme de Terre River, bed, 1,225; water, 1,226; grade	178·5	1261
Parkdale	179·3	1276
Sand Lake, water, 1,187; grade	185·7	1188
Summit, cutting 13 feet; grade	186·0	1197
Crossing the Northern Pacific, Fergus and Black Hills Railroad	186·3	1194
Fergus Falls, freight depot	186·5	1189
Red River, water, 1,178; grade	186·6	1190
Fergus Falls, passenger depot	187·2	1210
Summit, natural surface and grade	190·0	1237
Pelican River, water, 1,151; grade	191·8	1173
Carlisle	195·2	1226
Same, junction of branch to Elizabeth	195·5	1219
On this branch:		
Summit, cutting 8 feet; grade	197·2	1282
Summit, cutting 3 feet; grade	197·9	1284
Elizabeth	199·0	1257
On the main line northwestward:		
Lake, water, 1,220; grade	198·8	1225
Rothsay	203·8	1190
Lawndale, crest of Upper or Herman Beach of Lake Agassiz, excavated for ballast along a spur track extending a third of a mile north from the tank, 1,092–1,095; grade at tank	209·5	1089
Small beach deposits, crest and grade the same	210·6 and 210·7	1067
(Again small beach deposits are crossed at 211·2, 211·3, and 211·5 miles, with crests respectively at 1,057, 1,054, and 1,051 feet.)		
Tintah Beach of Lake Agassiz, crest and grade the same	217·6	1027
Barnesville	217·9	1020
Willow River (more commonly called Whiskey Creek), bed, 994; grade (at junction of line to Breckenridge)	218·3	1009
Junction of line to Moorhead	218·9	1000
Sieber's Creek, water, 979; grade	220·6	989
Buffalo Creek, tributary to the South Branch of Buffalo River, water, 957; grade	223·2	963
Downer	225·7	965
Glyndon, station and crossing the Northern Pacific Railroad	235·3	925
Buffalo River, bed, 903; water, 908; grade	236·9	921
Averill	241·8	917
Felton	249·6	915
Borup	254·9	911
Wild Rice River, bed, 895; water, 900; grade	262·6	909
Marsh River, water	264·6	890
Ada	265·2	906
Long Lake, former channel of the Wild Rice River, then passing westward in the present course of Marsh River, water	265·5	901

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Lockhart	275·0	893
Rolette	276·7	892
Beltrami	282·0	901
Sand Hill River, water, 895; grade	282·5	903
Russia	288·0	892
Kittson	292·3	885
Burnham Creek, water, 868; grade	293·0	882
Carman, junction of Fosston Branch	298.0	877
Red Lake River, water, 833; grade	299·0	863
Crookston	299·3	863
Bluff north of Red Lake River, natural surface, 886; grade	299·7	876
Junction with line to St. Vincent	300·5	885
Beach of Lake Agassiz, excavated for ballast, crest, 882; grade	302·8	879
Fisher	310·1	852
Grand Marais Slough (former channel of Red Lake River), bed, 830; grade	312·1	846
Mallory	317.5	837
East Grand Forks	323·4	831
Red River, bed, 779; lowest stage of water in ordinary years, 784–786; highest stage in ordinary years, 800–820; extreme high water (in spring, 1882), 828; grade	323·9	829
Grand Forks, 324·5 miles from St. Paul by this line, but only 320·3 miles by way of Moorhead	320·3	830
Junction of line to Neche	320·6	831
University	322·1	833
Grand Forks Junction, of line to Moorhead, 317·0 miles from St. Paul by that line	323·6	836
Salt Cooley, bed, 832; grade	330·1	850
Ojata	331·2	858
Beginning of ascent westward, natural surface, 862–865; grade	333·6	866
Crest of escarpment eroded in till, a beach of Lake Agassiz	333·9	880
Crest of next beach, a typical gravel ridge 10 feet above the surface eastward, 894; grade	335·7	893
Emerado	335·9	898
McCauleyville Beach, crest, 991; grade	340·8	985
(This beach ridge is about 50 rods wide (including the slopes); the descent from its crest is 18 feet to the east and 8 feet to the west.)		
Campbell Beach, crest, 1,014; grade	341·2	1003
(This beach ridge is about 60 rods wide; the descent from its crest is 23 feet to the east and 9 feet to the west.)		
Arvilla	342·0	1017
Lower Tintah Beach, crest	343·7	1055
Upper Tintah Beach, crest	344·1	1070
Lower Norcross Beach, crest	344·6	1080
Upper Norcross Beach, crest	345·0	1092
(These four beach ridges are small, being from 20 to 30 rods wide and 4 to 6 feet high.)		
Herman (*d*) Beach, represented by two or three such small beach ridges, crests	346·3–346·6	1118–1123
Herman (*c*) Beach, second ridge, crest and grade the same.	347·5	1134
(This beach ridge is 50 or 60 rods wide, and rises 9 feet above the land on each side.)		
Herman (*c*) Beach, first ridge, crest, 1,133; grade (at junction of line to Mayville and Portland)	347·8	1130
(This beach ridge is 40 rods wide, and rises 7 feet above the land on each side.)		

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Larimore, 346·7 miles from St. Paul by way of Portland, 345·9 miles by Mayville	348·2	1134
(The next 4 miles of this line are nearly level, with very slight undulations and small water courses, the elevation all the way being 1,130, or 2 or 3 feet above or below this.)		
Park River Junction, of line to Park River and Langdon.	350·6	1133
Herman (*b*) Beach, crest and grade the same	352·4	1146
(This beach ridge is about 20 rods wide (including the slopes); the descent from its crest is 10 feet to the east and 4 feet to the west.)		
Herman (*a*) Beach, marking the highest shore of Lake Agassiz, crest, 1,162; grade	352·8	1158
(This beach ridge is of similar size with the last. The next 12 miles westward have a very uniform and continuous ascent, with no evidences of shore lines.)		
Niagara	362·1	1440
Top of westward ascent, natural surface, 1,525; grade	365·0	1519
Lake, water, 1,515; grade	365·1	1520
Lake, water, 1,516; grade	366·4	1518
Petersburg	368·4	1519
(The surface in this vicinity is moderately undulating, with its crests 10 to 15 feet above the hollows and lakelets.)		
Slough, water, 1,522; grade	370·8	1525
Michigan City	374·1	1517
(The highest undulations crossed within 4 miles east and the same distance west from Michigan City rise only to 1,530 feet.)		
Mapes	378·9	1526
Depression, called "low bottom land," natural surface, 1,500–1,503; grade	382·0–382·6	1505
Lakota	384·7	1514
Summit, cutting 3 feet; grade (highest between the Red River and Devil's Lake)	385·6	1532
Bartlett	388·4	1529
(Thence an undulating surface slowly falls to 1,465–1,475 at 401 miles. In the next 8 miles west to Devil's Lake the surface continues very undulating, with its crests 10 to 25 feet above the depressions, nowhere rising so high as 1,500 feet.)		
Devil's Lake Station	409·0	1464
Leveling from this station, for the U. S. Geological Survey, gives the following:		
Devil's Lake, water (August 8, 1887)	.....	1431·6
Same, lowest and highest stages during the years 1880–1889	.....	1430–1434
Stump Lake, water (August 12, 1887)	.....	1417
(From a survey in June, 1887, for proposed waterworks for the city of Devil's Lake, the elevation of Sweetwater Lake at that date was ascertained to be 1,468 feet. Its lowest and highest stages are approximately 1,466–1,470 feet.)		
Grand Harbor	416·1	1454
Mauvaise Coulée, bed, 1,441; high water, 1,447; grade	427·4	1450
Church's Ferry, junction of the Cando Branch	427·9	1458
Summit, natural surface and grade	434·1	1527
Leeds	439·3	1514
Battle Creek, bed, 1,531; grade	442·8	1569
York	445·5	1612
Summit, cutting 5 feet; grade	447·4	1642

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Knox	451·6	1605
Broken Bone Summit, cutting 4 feet; grade	454·6	1655
Pleasant Lake Station	457·0	1603
Alkali flats, grade	458·5–459·5	1570
Rugby, junction of the Bottineau Branch	465·9	1561
Depression, "dry slough," natural surface, 1,484–85; grade	472·7–473·6	1489
Berwick	477·7	1482
Towner	485·0	1475
Mouse (or Souris) River, bed, about 1,441; high water, 1,455; grade	486·4	1458
Denbigh	491·2	1485
Granville	504·7	1503
Summit, grade (1 foot above the natural surface)	511·2	1544
Norwich	512·6	1526
Summit, natural surface and grade	519·5	1630
Mouse River, bed, 1,532; grade	526·5	1554
Minot	526·9	1557
Cut, 35 feet deep; grade	531·3	1671
(From 529 to 536·9 miles the surface ascending westward is very uneven, having frequent cuts and fills of 25 to 40 feet.)		
Gassman Coulée, bed, 1,568; bottom land, 1,585; grade	531·7	1682
(This is crossed by a trestle 95 to 100 feet high and 1,000 feet long.)		
Top of steep westwardly ascending grade (also the natural surface)	536·9	1847
(Thence a moderately undulating surface extends to the west.)		
Des Lacs	538·6	1897
Big Mary's Coulée, bed, 1,849; grade	541·1	1925
(This is crossed by a trestle 75 feet high and 400 feet long.)		
Lone Tree	544·9	1995
Berthold	549·7	2082
Creek, bed, 2,172; grade	554·2	2192
Summit, cutting 10 feet; grade	557·2	2236
Wallace	559·5	2182
Depression, natural surface, 2,165; grade	560·0	2177
Delta (a summit of grade, cutting 10 feet)	566·3	2258
Ravine, bed, 2,133; grade	570·7	2161
Elton	573·3	2195
Stanley	581·3	2252
Summit, cutting 5 feet; grade	583·6	2318
Ross	588·6	2287
Maniton	593·1	2275
White Earth River, bed, 2,067; water, 2,070; grade	600·2	2093
White Earth	600·5	2087
West Fork of White Earth River, bed, 2,091; water, 2,096; grade	603·1	2102
Tioga	610·0	2273
Summit, cutting 9 feet; grade	614·8	2347
Creek, bed, 2,239; grade	617·3	2272
Ray	618·3	2271
Creek, bed, 2,236; grade	621·0	2260
Summit of the Coteau du Missouri, cutting 4 feet; grade (highest between Devil's Lake and the Missouri River)	625·6	2391
Wheelock	626·1	2374
Spring Brook Station	634·5	2113
Avoca	641·7	1956
Little Muddy Creek, North Dakota, bed, 1,826; water, 1,828; grade	647·0	1854

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Missouri River at mouth of Little Muddy Creek, low and high water	647·0	1823–1846
Williston	648·4	1854
Missouri River here, low and high water	648·4	1825–1848
Missouri River, high water, 1887	650·4–651·4	1851
Cut, 46 feet deep, on the eastern boundary of the Fort Buford military reservation; grade	654·1	1874
Painted Wood Creek, bed, 1,847; grade	657·6	1864
Trenton	659·7	1894
Buford	668·6	1944
Missouri River here, at Fort Buford and mouth of the Yellowstone River, low and high water, about	668·6	1855–1875
Line between North Dakota and Montana, grade	670·9	1908
Willows	677·1	1889
Bottomland of the Missouri River here	677·1	1875
Missouri River, extreme high water, increased by ice gorge, 1881	678·0	1890
Little Muddy Creek, Montana, bed, 1,884; grade (Bridge No. 189)	681·1	1907
Same, bed, 1,905; grade (Bridge No. 195)	683·0	1926
Kilva	686·0	1955
Summit, cutting 2 feet; grade	688·7	2000
Lanark	693·1	1976
Western boundary of Fort Buford military reservation, grade	693·9	1971
Culbertson	700·5	1913
Big Muddy Creek, bed, 1,895; water, 1,901; grade	705·4	1918
Blair	706·6	1920
Missouri River, high water, 1861	708·3	1919
Calais	714·9	1934
Brockton	723·3	1945
Poplar	733·8	1955
Missouri River here, extreme low and high water	733·8	1935–1952·5
Poplar River, low and high water, 1,939–1,953; grade	734·4	1957
Chelsea	742·6	1980
Macon	748·7	1976
Wolf Point	754·6	1995
Wolf Creek, bed, 1,982; grade	756·6	2002
Missouri River, high water, 1888	759·4	1992
Oswego	766·1	2018
Lenox	773·1	2072
Kintyre	778·5	2082
Milk River Station	784·5	2048
Missouri River at mouth of Milk River, low and high water, about	784·5	2020–2040
East Fork of Big Porcupine Creek, bed, 2,033; grade	788·4	2057
Big Porcupine Creek, bed, 2,036; grade	789·2	2058
Nashua	790·1	2060
Whately	798·0	2086
Glasgow	804·3	2087
Milk River, first crossing, bed, 2,049; grade	806·6	2092
Stockholm	809·1	2093
Antelope Creek, bed, 2,076; grade	811·3	2098
Tampico	814·9	2105
Summit, cutting 2 feet; grade	817·9	2146
Vandalia	821·4	2120
Hinsdale	829·0	2162
Beaver Creek, first crossing, bed, 2,145; water, 2,153; grade	837·4	2170
Beaverton	838·3	2168
Beaver Creek, second crossing, bed, 2,153; grade	839·9	2172
Same, third crossing, bed, 2,154; grade	840·7	2173

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Saco	843·0	2175
Beaver Creek, fourth crossing, bed, 2,159; high water, 2,175; grade	843·5	2178
Ashfield	853·0	2205
Beaver Creek, fifth crossing, bed, 2,185; low water, 2,188; grade	853·4	2207
Bowdoin	861·2	2209
Malta	870·1	2242
Milk River, second crossing, bed, 2,211; ordinary stage of water, 2,220; high water, 2,239; grade	870·4	2245
Exeter	874·9	2254
Wagner	881·2	2258
Dodson	887·5	2279
Eureka (a summit of grade)	893·2	2301
Savoy (also a summit of grade)	900·5	2324
Wayne	906·0	2332
Parallel Creek, bed, 2,326; grade	913·0	2346
Harlem	914·6	2359
Zurich	922·9	2368
Morris Creek, bed, 2,361; grade	925·7	2375
East Fork of Milk River, bed and water, about 2,361; grade	929·6	2381
North Fork Station	930·0	2381
West Fork of Milk River, grade	934·9	2397
Chinook (Fort Belknap)	936·3	2401
Milk River, third crossing, bed, 2,403; water, 2,406; grade	941·7	2423
Yantic	943·8	2431
Milk River, fourth crossing, bed, 2,421; grade	947·0	2443
Same, fifth crossing, bed, 2,421; grade	947·4	2444
Box Elder Creek, bed, 2,437; grade	950·2	2454
Toledo	950·5	2455
Havre	957·5	2472
Assiniboine	964·9	2576
Laredo	972·2	2627
Box Elder	981·9	2669
Box Elder Creek, bed, 2,647; grade	982·7	2664
Big Sandy Station	992·6	2690
Verona	998·3	2708
Coal Banks Coulée, bed, 2,754; grade	1002·3	2793
Cairo	1005·1	2837
Dry Fork siding	1011·7	2984
Dry Fork summit, cutting 4 feet; grade (A slightly undulating profile, with no deep cutting, reaches across the watershed that divides the Milk and Missouri Rivers, to this summit, which lies within the Upper Missouri basin. Descending beyond Dry Fork summit, a gradient of 53 feet per mile reaches from 1,013·2 miles, grade, 2,979, to 1,017·8 miles, grade, 2,735.)	1012·4	3004
Marias River, bed, 2,545; grade	1021·7	2564
Missouri River at mouth of Marias River, low and high water, about	1021·7	2545–2560
Marias	1022·3	2561
Teton River, bed, 2,544; grade	1023·0	2563
Teton	1027·4	2626
In Government Coulée, very steep ascent, grade	1029·1 to 1030·6	2658–2834
Summit of ascending grade	1030·8	2848
Benton	1033·7	2850
Missouri River at Fort Benton, ordinary stage of water, about	1033·7	2565

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Tunis	1040·9	2957
Sidney	1047·0	3098
Flowerree	1052·0	3203
Huntley Coulée, bed, 3 163; grade	1053·2	3227
Summit, cutting 3 feet; grade	1055·9	3364
Reef Coulée, bed, 3,291; grade	1057·2	3318
Portage	1059·3	3413
Missouri River at mouth of Portage River (Highwood Creek), foot of series of falls and of portage 18 miles long	1059·3	2783
Summit, cutting 10 feet; grade	1061·9	3502
Portage Coulée, bed, 3,455; grade	1062·1	3499
Depression, crossing Black Horse Lake, surface, 3,398–3,401; grade	1064·6 to 1065·9	3403
Watson	1068·5	3470
Summit, grade (1 foot above natural surface)	1069·1	3480
Johnstown, junction of spur track to Great Falls	1075·7	3311
Sun River, bed, 3,291; ordinary stage of water, 3,299; high water, 3,306; grade	1076·0	3320
Missouri River at mouth of Sun River, ordinary low stage and high water	1076·0	3299–3306
Connection with the Montana Central Railway, at southwest end of the bridge over Sun River, grade	1076·05	3321
On the spur track to Great Falls:		
Missouri River, at head of portage and succession of falls and rapids extending 18 miles, reported to amount in total to 512 feet, ordinary stage of water, 3,295; high water, 3,302; grade on bridge	1076·2 to 1076·4	3312
Great Falls	1076·7	3312

PRINCETON BRANCH, ELK RIVER TO MILACA.

[This agrees exactly at Milaca Junction.]

Elk River Station	38·5	892
Junction with the main line (Elk River Junction)	39·2	905
Summit, cutting 10 feet; grade	42·0	971
Second summit, cutting 10 feet; grade	49·5	992
Princeton	57·5	974
West Branch of Rum River, bed, 952; water (mill-pond), 959; high water, 964; grade	58·4	970
Mouth of the West Branch of Rum River, water	58·4	950
Milaca Junction, line from Duluth to St. Cloud and Sioux Falls	71·0	1070
Milaca	71·6	1072

SAUK CENTER AND NORTHERN BRANCH.

Sauk Center	116·8	1255
Same, junction with the main line	117·3	1257
Hobogan Creek, water, 1,232; grade	117·7	1248
Ashley Creek, water, 1,241; grade	120·4	1259
Summit, cutting 8 feet; grade	122·0	1300
Creek, water, 1,261; grade	122·8	1271
Little Sauk	126·8	1253
Sauk River, water, 1,240; grade	126·9	1253
Summit, natural surface and grade	129·6	1347
Creek, water, 1,296; grade	134·5	1301

GREAT NORTHERN RAILWAY SYSTEM—Continued.

SAUK CENTER AND NORTHERN BRANCH—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Long Prairie	135·4	1299
Long Prairie River, water, 1,287; grade	135·7	1294
Dick's Creek, water, 1,269; grade	142·8	1279
Browerville	143·0	1282
Clarissa	148·6	1332
Eagle Creek, water, 1,329; grade	150·1	1339
Same, water, 1,346; grade	152·3	1354
Eagle Bend, about	153·2	1360

EVANSVILLE AND TINTAH BRANCH.

[This agrees with the Minneapolis and Pacific Railway near Elbow Lake, and with the Breckenridge line at Tintah.]

Evansville, junction with Fergus Falls line	159·2	1353
Summit, cutting 13 feet, grade	159·9	1367
Erdahl	166·0	1266
Pomme de Terre River, bed, 1,157; water, 1,160; grade	170·7	1188
Thorsborg	171·3	1206
Summit, cutting 2 feet; grade	172·4	1239
Crossing the Minneapolis and Pacific Railway	174·3	1201
Elbow Lake Station	176 1	1197
Depression, filling 15 feet; grade	179·9	1113
Summit, natural surface and grade	180·8	1140
Hereford	183·8	1078
Herman Beaches of Lake Agassiz, crests, respectively	184·4 and 184·4	1078 and 1076
Tintah, junction with the Breckenridge division and station, 193·0 miles from St. Paul by main line of that division	192·3	997

PELICAN RAPIDS BRANCH.

[Proved to be correct by the agreement of two independent surveys.]

Fergus Falls, passenger depot	187·2	1210
Same, crossing the Northern Pacific, Fergus and Black Hills Railroad	186·3	1194
Pelican Junction, Northern Pacific, Fergus and Black Hills Railroad	186·5	1189
Red River, water, 1,178; grade	186·7	1189
Summit, cutting 4 feet; grade	190·6	1254
Depression, filling 4 feet; grade	192·8	1211
Elizabeth	194·4	1240
Pelican River, first crossing, bed, 1,222; grade	195·3	1239
Same, second crossing, bed, 1,227; grade	196·1	1239
Same, third crossing, bed, 1,233; grade	196·4	1249
Summit, level grade	201·2–201·6	1295
Erhart's	201·9	1286
Pelican River, fourth crossing, bed, 1,269; grade	203·2	1277
Summit, cutting 3 feet; grade	204·9	1308
Pelican River, fifth crossing, bed, 1,278; grade	205·2	1295
Same, sixth crossing, bed, 1,282; grade	206·0	1289
Summit, natural surface and grade	207·3	1311
Pelican Rapids	207·9	1304
Pelican River, water below and above the dam at Pelican Rapids	207·9	1291–1303

GREAT NORTHERN RAILWAY SYSTEM—Continued.

FOSSTON BRANCH.

The profile here receives a subtraction of 5 feet at Carman, like the main line; and thence east to the crossing of the Duluth and Manitoba Railroad, a uniform subtraction of 7 feet. At this crossing, and also at Leech Lake, the elevation of which is determined by United States engineers, it requires a subtraction of 9 feet, which accordingly is made throughout that portion.

	From Carman.	Above the sea.
	Miles.	*Feet.*
Carman, junction with main line near Crookston, 298·0 miles from St. Paul	0·0	877
Burwell	6·1	914
Benoit	11·7	1019
Beach of Lake Agassiz, 15 rods wide, crest, 1,062; grade	14·2	1063
Beach, crest (site of the Pembina trail), 1,069; grade	14·3	1067
[This beach ridge is 12 rods wide from its west base (1,062 feet) to its east base (1,065 feet).]		
Beach 15 rods east of the last, crest, 1,069; grade	14·35	1068
Beach, crest, 1,092; grade	15.6	1089
(The descent from the crest is 11 feet in 12 rods to the west, and 4 feet in 10 rods to the east. From ¼ to ½ of a mile west of this beach, natural surface and grade are 1,085–1,082, probably marking deposits formed contemporaneously in the margin of the lake. Intervening between this belt and the beach, a depression at 15·1 to 15·5 miles sinks to 1,079–1,081 feet.)		
Beach, crest, 1,114; grade	16·9	1110
(This is a very massive beach ridge, having a descent of 18 feet westward from its crest in 50 rods, and of 8 feet eastward in 30 rods.)		
Beach, crest, 1,120; grade, crossing the Duluth and Manitoba Railroad	17·4	1116
Beach, crest, 1,142; grade	18·1	1138
Dugdale	18·2	1138
Junction of branch graded toward Pelican Rapids	18·5	1142
On this branch:		
Sand Hill River near center of Sec. 13, Garfield (T. 147, R. 44), low water, 1,116; grade	29·7	1145
Summit, natural surface and grade	33·0	1195
Creek tributary to Wild Rice River, crossed in Sec. 36, Strand (T. 145, R. 44), bed, 1,072; grade	44·1	1107
Wild Rice River in SW. ¼ of Sec. 25, Wild Rice (T. 144, R. 44), bed, 1,023; water, 1,025; grade	49·8	1091
End of located line, natural surface, 1,177; grade	53·5	1174
On the line from Dugdale eastward:		
Crest of eastward ascent; grade	19·3	1163
(The surface is 1,161 to 1,167 feet thence to 23·4 miles. Small beaches are crossed at 22·4 and 22·5 miles, with their crests respectively at 1,166 and 1,167 feet.)		
Mentor	23·7	1167
Hay Creek, one of the outlets of Maple Lake, bed, 1,156; grade	23·9	1165
Maple Lake, water	23·9	1169
Summit, natural surface, 1,169; grade	25·1	1171
Badger Lake, water, 1,172; grade	29·5	1178
Erskine	30·3	1187
(Morainic contour extends from 31·0 to 33·0 miles, and is succeeded by a moderately rolling surface farther east.)		
Ravine between two lakes, bed, 1,199; grade	31·9	1224
McIntosh	36·5	1218
Poplar River, bed, 1,200; water, 1,204; grade	37·4	1211
(The next ¼ mile east has a morainic surface.)		

GREAT NORTHERN RAILWAY SYSTEM—Continued.

FOSSTON BRANCH—Continued.

	From Carman.	Above the sea.
	Miles.	*Feet.*
Fosston	44·0	1288
End of track-laying November 20, 1888	44·7	1291
On line surveyed for continuation of this branch east-southeast to the southwest arm of Leech Lake:		
Summit near the east line of Sec. 35, T. 147, R. 39	53·5	1545
Lakes ¼ mile east and southeast from the last, the most southern being called Long Lake	54·2	1485
Head stream of Clearwater River, bed (mud to depth of 10 feet)	56·1	1439
Creek tributary to Lower Rice Lake, bed, 1,466; bottom land, 1,469	61·8	1466
Mississippi River (about 30 feet wide), bed, 1,371; water, 1,373; bottom land, 25 to 50 rods wide, 1,376; proposed grade of bridge	77·1	1409
(This crossing is distant about 11 miles in a straight line northward from Lake Itasca, being in Sec. 8, T. 145, R. 35.)		
Creek, bed	87·5	1381
(Within ¼ mile both west and east the surface rises to 1,450–1,460 feet.)		
Schoolcraft River, the "East Fork of the Mississippi," called La Place River by Nicollet's map, bed	89·9	1372
(Roughly morainic contour, with elevations 25 to 100 feet above the hollows, extends from 91·0 miles to Leech Lake, a distance of 30 miles.)		
Summit, highest on this line of survey	98·5	1576
Leech Lake, water, raised by dam	121·2	1297

ST. VINCENT LINE.

The profile requires, as noted on page 69, a uniform subtraction of 5 feet, which is here made, giving exact agreement with the Emerson Branch of the Canadian Pacific Railway on the international boundary.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Crookston	299·3	863
Junction with main line to Grand Forks and Great Falls	300·5	885
Shirley, junction of the St. Hilaire Branch	305·8	900
Euclid	313·2	890
Angus	321·1	870
Warren	329·8	853
Snake River, water, 838; grade	330·2	855
Argyle	339·6	845
Middle River, bed, 828; water, 831; grade	340·2	842
Tamarack River, bed, 811; water, 814; grade	347·7	827
Stephen	348·1	827
Donaldson	356·6	826
Kennedy	361·4	825
Hallock	370·5	815
South Branch of Two Rivers, bed, 791; water, 800; grade	371·7	813
Northcote	376·1	802
North Branch of Two Rivers, bed, 778; water, 784; grade	376·5	798
Humboldt	382·9	792
St. Vincent, switch of line to Emerson and Winnipeg	389·2	787
St. Vincent depot	390·2	787

GREAT NORTHERN RAILWAY SYSTEM—Continued.

ST. VINCENT LINE—Continued.

	From St. Paul.	Above the sea
	Miles.	*Feet.*
Red River at St. Vincent, bed, 739; extreme low water, 748; usual water surface, 753; high water of 1866, 782; extreme high water (1882)	390·2	788
Grade on the international boundary	391·2	790
Red River here, high water of 1882	391·2	786·5
Emerson, on branch of Canadian Pacific Railway	391·3	790

ST. HILAIRE BRANCH.

Shirley, junction with the St. Vincent line	305·8	900
Ives, crossing of the old Pembina trail	314·4	986
(This is on the Lower McCauleyville Beach of Lake Agassiz, which is cut 4 or 5 feet across its width of about 20 rods; crest of the beach ridge, 990 feet.)		
Upper McCauleyville Beach, crest, 997; grade	314·7	993
Little Black Creek, water, 975; grade	315·4	987
Black River, water, 970; grade	318·0	997
Campbell Beach, crest, 1,019, 6 feet above the land next east; grade	318·5	1011
Beginning of nearly level grade eastward, natural surface and grade the same	323·2	1078
(Thence a slightly undulating surface, with indistinct Lower Norcross Beaches, extends to St. Hilaire and the Red Lake River.)		
St. Hilaire	327·3	1086
Red Lake River, about	327·3	1065

ST. JOHN BRANCH.

Church's Ferry, junction with main line to Great Falls	427·9	1458
(Thence north to Cando the surface is slightly undulating, with an average ascent of 2 feet per mile.)		
Cando	443·3	1488
Coulée, bed, 1,470; grade	444·0	1480
Coulée, bed, 1,572; grade	455·1	1585
Bisbee	456·0	1600
Perth	463·0	1731
Big Coulée, bed, 1,754; grade	469·8	1776
Rolla	475·3	1818
St. John	482·6	1945

BOTTINEAU BRANCH.

Rugby Junction, main line to Great Falls	465·9	1561
Same, switch of this branch	466·2	1558
Creek, bed, 1,465; grade	474·9	1472
Barton	478·7	1505
Willow City	487·0	1471
Willow River, bed, 1,458; high water, 1,464; grade	487·5	1469
Oak Creek, bed, 1,617; grade	503·7	1631
Bottineau	504·0	1638

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE, FROM ST. PAUL, BY WILLMAR, BRECKENRIDGE, MOORHE GRAND FORKS, TO NECHE.

After the correction of the line from Crookston to Grand Forks and wes noted on page 69, this profile agrees with the numerous intersections of br this system and of other railways along its entire extent.

	From St. Paul.	Abc
	Miles.	
St. Paul	0·0	
Minneapolis	10·3	
Clearwater Junction, branch to Clearwater and St. Cloud	12·0	
Cedar Lake, water, 858; grade	13·1	
Cedar Lake Station	13·6	
Hutchinson Junction, branch to Hutchinson	16·5	
Victoria Lake, water, 896; grade	17·1	
St. Albans	20·0	
Wayzata	24·0	
Lake Minnetonka, water	24·0	
Long Lake Station	26·8	
Summit, grade	31·9	
Maple Plain	32·1	
Armstrong	33·2	
Delano	38·8	
South Fork of Crow River, water, 910; grade	38·9	
Montrose	45·5	
Waverly	48·1	
Waverly Lake, water	48·1	
Twelve Mile Creek, water, 961; grade	50·3	
Howard Lake Station	53·4	
Smith Lake Station	56·1	
Sucker Creek, water, 994; grade	58·8	
Cokato	59·5	
Cokato Lake, 2 miles northeast, water	59·5	
Collinwood Creek, water, 1,020; grade	62·8	
Creek next west, flowing north, water, 1,027; grade	63·9	
Dassel	65.3	
Summit, grade	66·4	
Washington Creek, water, 1,066; grade	67·6	
Summit, grade	68·4	
Darwin	70·6	
Litchfield	76·5	
Outlet of Lake Ripley, water, 1,106; grade	77·1	
Outlet of Long Lake, water, 1,142; grade	82·9	
Grove City (formerly Swede Grove)	84·3	
Summit, Anderson's Hill, cutting 15 feet; grade	87·6	
Atwater	89·4	
Summit, cutting 3 feet; grade, highest point on this railway line	94·3	
Kandiyohi	96·8	
Willmar Junction, of line from Duluth to Sioux Falls	101·3	
Willmar	102·5	
Junction of the Willmar and Sioux Falls Railway	103·0	
Pennock (St. John's)	109·1	
Shakopee Creek, water, 1,086; grade	115·4	
Kerkhoven	116·6	
De Graff	125·6	
Cut, 16 feet deep; grade	130·8	
Benson	132·9	
Chippewa River, water, 1,022; grade	133·8	
Junction of the Watertown and Huron Branch	133·9	
Clontarf	135·7	
Hancock	148·9	
Summit, cutting only 1 foot; grade	150·4	
Pomme de Terre River, water, 1,068; grade	153·9	
Junction of the Brown's Valley Branch	156·3	

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE, FROM ST. PAUL TO NECHE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Morris	157·4	1131
Summit, grade	159·4	1158
Donnelly	166·0	1126
New Moose Island tank	171·2	1095
Moose Island Station, at old tank and section house	171·7	1087
Herman	176·5	1072
Edge of eroded low escarpment of till, natural surface, 1,076; grade	177·8	1073
Upper or Herman Beach of Lake Agassiz, crest, 1,068; grade	178·1	1062
Base of this beach ridge on its northwest side, natural surface, 1,051; grade	178·3	1054
Norcross, depot on crest of the Norcross Beach, crest and grade the same	181·2	1041
(This beach ridge is about 30 rods wide, with descent of 2 feet from its crest to the southeast and 8 feet to the northwest.)		
Mustinka Creek, water, 1,020; grade	182·9	1028
Gorton	183·8	1024
Tintah, junction of branch from Evansville	193·0	997
Tintah Junction, Aberdeen Branch	197·2	988
Rabbit River, grade	199·4	984
Campbell	200·1	984
Doran	207·3	973
Breckenridge, junction with branch to Barnesville	214·6	961
Red River of the North, ordinary stage of low water, at the mouth of the Bois des Sioux River	214·9	943
Bois des Sioux River, bed, 944; grade	214·9	962
Wahpeton	215·7	965
Junction with line to Everest and Larimore	216·7	963
Crossing the Fargo and Southern (Chicago, Milwaukee and St. Paul) Railway	220·2	960
Lehigh	222·0	957
Red River, bed, 928; water, 931; grade	222·7	955
Kent	229·0	942
Whiskey Creek, bed, 915; grade	229·3	942
Wolverton	238·0	929
Holy Cross	244·8	921
Cooley, bed, 899; grade	246·6	917
Elmer	250·0	912
Finkle	255·5	912
Junction with line from Barnesville and crossing the Northern Pacific Railroad	259·6	906
Moorhead, 260·2 miles from St. Paul by this line, but only 241·3 miles by way of St. Cloud and Barnesville	241·3	904
Red River, bed, 861; ordinary low water, 870; high water in ordinary years, 880–890; extreme high water (1882), 898; grade	241·7	903
Fargo	242·3	902
Harwood	250·7	886
Sheyenne River, bed, 858; water, 862; grade	252·2	886
Argusville	256·4	884
Gardner	262·6	886
Grandin	269·3	891
Elm River, water, 865; grade	270·0	893
Kelso	275·4	897
North Branch of Elm River, water, 888; grade	275·6	898
Alton	277·7	898
Hillsboro	281·1	901
Goose River, water, 872; grade	281·9	896
Cummings	288·9	928
Buxton	295·0	930

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE, FROM ST. PAUL TO NECHE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
"Hubbard pit," an excavation for gravel ballast in a beach of Lake Agassiz, crest of beach, 928; grade..... (This beach ridge is about 30 rods wide; the descent from its crest is 5 or 6 feet to the south and 8 feet to the north.)	298·3	922
Reynolds	299·8	910
Thompson	307·1	865
Grand Forks Junction, on line to Great Falls, 3½ miles west of Grand Forks	317·0	836
University	318·5	833
Grand Forks, 324·5 miles from St. Paul by way of St. Cloud, Fergus Falls, and Crookston	320·3	830
English Cooley, bed, 795; high water, 809; grade	323·1	825
Schurmeier	326·7	826
Manvel	333·2	819
Turtle River, low water, 798; high water, 812; grade	334·1	816
Levant	340·4	822
Ardock	345·0	824
Forest River, low and high water, 799–808; grade	350·9	816
Minto	351·3	820
Grafton	360·2	827
Park River, low and high water, 809–819; grade	360·6	827
Auburn	366·5	842
Willow Creek, bed, 830; grade	373·5	840
St. Thomas	374·1	840
Glasston	3[illegible]0·2	836
Hamilton	387·1	824
Bathgate	392·3	821
Tongue River, bed, 801; low and high water, 803–816; grade	392·5	821
Neche	400·1	831
Pembina River, bed, 810; low and high water, 813–832; grade	400·8	837
Grade on the international boundary	401·5	830
Gretna, on branch of the Canadian Pacific Railway	401·8	829

CLEARWATER BRANCH, FROM MINNEAPOLIS TO ST. CLOUD.

This agrees exactly with the Fergus Falls line at St. Cloud.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Minneapolis	10·3	81[illegible]
Clearwater Junction, with the Breckenridge line	12·0	81[illegible]
Parker	17·2	8[illegible]
Shingle Creek, bed, 864; water, 867; grade	21·8	87[illegible]
Osseo	23·8	8[illegible]
Elm Creek, bed, 871; water, 874; grade	26·4	88[illegible]
Rush Creek, bed, 898; water, 902; grade	29·1	9[illegible]
Maple Grove	29·8	94[illegible]
Hassan	34·0	9[illegible]
Crow River, bed, 852; water, 855; grade	35·4	[illegible]
St. Michael's	39·0	9[illegible]
Summit, cutting 15 feet; grade	42·1	9[illegible]
Monticello	47·4	9[illegible]
Silver Creek Station (a summit of grade)	55·0	10[illegible]
Silver Creek, bed, 961; water, 963; grade	56·3	97[illegible]
Rice Lake Marsh, natural surface, 953; grade	57·8	960

GREAT NORTHERN RAILWAY SYSTEM—Continued.

CLEARWATER BRANCH, FROM MINNEAPOLIS TO ST. CLOUD—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Rice Creek, bed, 950; water, 952; grade	58·5	962
Clearwater	62·2	960
Clearwater River, bed, 931; ordinary low water at its junction with the Mississippi, 936; high water (of Mississippi River), 954; grade	62·5	960
(This crossing is close below the lowest dam of the Clearwater River, and is only a few rods from its mouth.)		
Plum Creek, bed, 950; water, 953; grade	64·1	963
Summit, natural surface and grade	66·4	1006
St. Augusta Creek, bed, 952; water, 955; grade	68·2	983
St. Augusta	69·2	1014
Three Mile Creek, bed, 983; water, 991; grade	71·2	1012
Summit, natural surface and grade	73·7	1046
Junction with the St. Cloud and Fergus Falls main line	75·0	1040
St. Cloud, 74·6 miles from St. Paul by way of Anoka and Elk River	75·4	1037

HUTCHINSON BRANCH.

This agrees with connecting railways and other surveys at Excelsior and Hutchinson.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Hutchinson Junction, with the Breckenridge line	16·5	903
Minnehaha Creek, water, 896; grade	18·1	912
Summit, cutting 27 feet; grade	21·5	970
Depression, filling 10 feet; grade	22·6	923
Summit, cutting 10 feet; grade	24·1	962
Purgatory Creek, bed, 876; grade	24·9	914
Summit, grade	26·9	992
Road on bridge over railway, 1,011; grade	27·1	983
Crossing the Minneapolis and St. Louis Railway	28·2	938
Lake Minnetonka, low and high water	28·2	925–929
Excelsior	28·7	944
Same, grade near the Minneapolis and St. Louis depot, at same elevation with it	29·2	947
Centennial Lake, water, 945; grade	34·0	952
Six Mile Creek, bed, 926; grade	38·5	945
Clearwater Lake, water, 963; grade	40·2	973
Coney Island Station	40·9	971
Summit, cutting 19 feet; grade	43·5	1000
Mayer	47·3	955
South Fork of Crow River, bed, 930; low and high water, 932–937; grade	47·4	955
Crane Creek, water, 951; grade	51·8	960
Otter Creek, bed, 955; grade	52·4	964
Lester Prairie	53·8	982
Summit, cutting 7 feet; grade	60·9	1057
Silver Lake Station	61·4	1052
Outlet of Silver Lake, bed, 1,031; grade	62·2	1042
Bear Creek, bed, 1,026; grade	62·8	1042
Summit, cutting 10 feet; grade	67·7	1070
South Fork of Crow River, bed, 1,023; water, 1,026; grade	68·9	1045
Same, water below and above the dam, at Hutchinson, flowing Otter Lake, about	69·5	1029–1038
Hutchinson	69·5	1040

GREAT NORTHERN RAILWAY SYSTEM—Continued.

WATERTOWN AND HURON BRANCH.

[The portion from Watertown to Huron is operated under a lease from the Duluth, Watertown and Pacific Railroad Company.]

In agreement with connecting railways at Watertown and Huron.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Junction with the Breckenridge line, 1 mile west of Benson	133·9	1037
Mud Creek, bed, 1,023; grade	137·6	1029
Dead Man's Slough, natural surface, 1,019–1,020; grade	144·1–144·5	1023
Pomme de Terre River, bed, 1,003; water, 1,005; grade	153·1	1020
Appleton	154·8	1015
Pomme de Terre River, bed, 980; water, 983; grade (This is near the intersection of the Hastings and Dakota Division of the Chicago, Milwaukee and St. Paul Railway.)	155·5	1005
Minnesota River, bed, 933; low water, 935; bottom land, 935–938; grade	159·8	944
Louisburg	163·8	1042
Bellingham	170·3	1049
Boat Creek, tributary to the South Fork of the Yellow Bank River, bed, 1,087; grade	177·5	1098
Nassau	179·2	1122
Line between Minnesota and South Dakota, grade	179·5	1122
Albee (Walrath)	184·7	1184
La Bolt	190·8	1362
Summit, natural surface and grade	208·0	1926
Forrestville	211 5	1868
Ranville	218·7	1757
Crossing the Chicago and Northwestern Railway	224·5	1726
Watertown (This depot is 7 feet lower than that of the Chicago and Northwestern Railway.)	224·9	1726
Big Sioux River, bed, 1,708; low and high water, 1,709–1,715; grade	225·2	1718
Depression at Pelican Lake, grade	226·7–227·1	1716
Thompson Creek, bed, 1,726; grade	230·9	1750
Grover	234·7	1742
Hazel	241·1	1765
Crossing the Chicago, Milwaukee and St. Paul Railway.	248·0	1829
Vienna (a summit of grade)	248·5	1837
Willow Lakes Station	256·9	1786
Red Stone Creek, bed, 1,684; grade	264·6	1695
Same, bed, 1,669; grade	264·8	1687
Same, bed, 1,553; grade	268·6	1569
Bancroft	269·0	1561
Iroquois Creek, bed, 1,440; grade	273·2	1456
Osceola	273·6	1453
Pearl Creek, bed, 1,346; grade	279·4	1355
Yale	281·2	1340
Sheffield	288·6	1300
James River, bed, 1,221; low and high water, 1,227–1,246; grade	291·0	1261
Crossing the Dakota Central Division of the Chicago and Northwestern Railway	293·9	1282
Huron	294·3	1287

GREAT NORTHERN RAILWAY SYSTEM—Continued.

BROWN'S VALLEY BRANCH.

This agrees with the Fargo and Southern Railway at Graceville, and with leveling for the U. S. Geological Survey of Lake Agassiz at Brown's Valley.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Junction with the Breckenridge line near Morris	156·3	1122
Summits, each cutting 4 feet; grade alike	158·3 and 159·1	1140
Mud Creek, water, 1,078; grade	160·2	1105
Wheeler	163·5	1112
Chokio	169·6	1124
Johnson	175·6	1129
Crossing the Fargo and Southern (Chicago, Milwaukee and St. Paul) Railway	182·2	1112
Graceville	182·6	1109
Barry	188·4	1107
Beardsley	195·8	1098
Top of the bluff east of Brown's Valley, grade	199·4	1098
Depression at foot of this bluff, surface	202·3	975
Brown's Valley	202·7	980
Minnesota River, low water	202·7	972
Lake Traverse, 1 mile north, low and high water, 970–976; ordinary stages of water	202·7	971–973

ABERDEEN BRANCH.

This agrees exactly or closely where it crosses the Fargo and Southern (Chicago, Milwaukee and St. Paul) and Minneapolis and Pacific Railways, and with connecting railways at Aberdeen.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Tintah Junction, Breckenridge line	197·2	988
South Branch of Rabbit River, bed, 969; high water, 982; grade	197·9	988
Campbell Beach of Lake Agassiz, rising 5 feet above the adjoining area westward, crest, 989; grade	200·6	990
Childs	205·1	977
Bois des Sioux River, bed, 961; bottom land, 967; grade	206·6	972
Crossing the Fargo and Southern (Chicago, Milwaukee and St. Paul) Railway	208·6	985
Campbell Beach, crest, 987; grade	210·3	988
De Villo	210·4	987
Sonora	215·2	988
(The profile shows in several places dunes 3 to 6 feet high, but no distinct beach, between Sonora and Hankinson.)		
Hankinson	222·7	1068
Milnor Beach of Lake Agassiz, crest, 1,089; grade	224·7	1088
Crossing the Minneapolis and Pacific Railway	225·2	1088
Stiles	229·9	1139
Summit, cutting 5 feet; grade	231·4	1153
Lidgerwood	234·5	1122
Geneseo	240·8	1164
Summit, grade	242·1	1170
Cayuga (a summit of grade)	245·9	1140

GREAT NORTHERN RAILWAY SYSTEM—Continued.

ABERDEEN BRANCH—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Wild Rice River, bed, 1,118; grade	246·3	1132
Rutland, junction of the Ellendale Branch	252·1	1225
Wild Rice River, bed, 1,202; grade	254·3	1216
Sprague Lake Station	255·0	1219
Havana (a summit of grade)	261·3	1294
Kidder	268·0	1295
Crossing the Chicago, Milwaukee and St. Paul Railway	271·5	1309
Burch	275·1	1296
(At this station and for a half mile westward the surface consists of dunes 5 to 10 feet in height, with their crests at 1,296 to 1,299 feet. Through the next 4 miles southwestward the surface is very flat, 1,293 to 1,294 feet. Thence numerous small dunes, with crests at 1,294 to 1,308 feet, are crossed in the distance of 2¼ miles to Amherst. These are part of a north to south belt of dunes (also crossed by the Ellendale Branch) uplifted by the wind from the silty deposits of Lake Dakota, which, as shown by Prof. J. E. Todd, occupied the James River Valley along an extent of about 170 miles from Mitchell to Oakes during the recession of the ice-sheet.)		
Amherst (a summit of grade)	281·9	1312
Claremont	288·5	1302
Huffton	293·9	1307
Putney	299·3	1306
James River water-tank, grade	302·5	1284
James River, bed, 1,269; water, 1,272; grade	303·3	1286
Plana	307·0	1302
Moccasin Creek bed, 1,284; water, 1,286; grade	314·1	1297
Crossing the Chicago, Milwaukee and St. Paul and Chicago and Northwestern Railways	315·6	1300
Aberdeen	316·0	1300

ELLENDALE BRANCH.

Agreeing with the Chicago, Milwaukee and St. Paul Railway at Ellendale.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Rutland, junction with the Aberdeen Branch	252·1	1225
Depression, grade	253·1	1217
Belle Plaine	258·9	1270
Summit, cutting 2 feet; grade	261·6	1319
Brookland	263·9	1304
Crossing the Chicago, Milwaukee and St. Paul Railway	265·1	1299
Lake bed, natural surface, 1,286–1,287; grade	268·8–269·4	1290
Straubville	270·9	1314
Summit, cutting 6 feet; grade (crossing a morainic belt)	274·1	1346
Dunes, natural surface, 1,314–1,324; grade	275·1–275·6	1319
Crescent Hill Station	277·0	1313
(Small dunes, crests, 1,315–1,312 feet, are crossed at 277·6 to 278·6 miles.)		
Riverdale	281·0	1304
Crossing the Chicago and Northwestern Railway	281·8	1303
James River, bed, 1,283; low water, level with the dam at Columbia, 1,286; high water (1882), 1,292; grade	282·7	1296

GREAT NORTHERN RAILWAY SYSTEM—Continued.

ELLENDALE BRANCH—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Guelph (a summit of grade)	287·0	1369
Depression, bed of culvert, 1,342; grade	287·5	1354
Summit, cutting 8 feet; grade	291·9	1415
Silver Leaf	293·9	1405
Maple River, bed, 1,370; high water, 1,382; grade	295·5	1386
Ellendale	301·0	1453
Same, junction with the Chicago, Milwaukee and St. Paul Railway	301·3	1453

BRECKENRIDGE TO MOORHEAD BY WAY OF BARNESVILLE.

Agreeing with other portions of this railway system and with other railways at Barnesville and Moorhead.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Breckenridge	214·6	961
Red River, water, 951; grade	215·6	965
Manston	231·1	978
Mushroom Creek (head of South Branch of Buffalo River), water, 974; grade	234·1	981
Deer Horn Creek, water, 972; grade	237·8	982
Atherton	237·9	981
Junction with the main line by St. Cloud and Crookston to Great Falls, 0·4 mile north of Barnesville	243·1	1009
Willow River (more commonly called Whiskey Creek), bed, 994; grade (at junction, 243·1 miles of this line from Breckenridge)	218·3	1009
Barnesville depot, 217·9 miles from St. Paul by way of the St. Cloud and Fergus Falls Division, but 243·5 miles by way of Breckenridge	217·9	1020
Junction with main line to Crookston and Great Falls	218·9	1000
Baker	225·1	944
South Branch of Buffalo River, bed, 908; grade	231·4	922
Sabin	232·4	930
Crossing the Northern Pacific Railroad	240·7	906
Moorhead	241·3	904

MOORHEAD NORTHERN BRANCH.

Junction with line from Barnesville a half mile east of Moorhead	240·8	906
Kragnes	249·0	892
Buffalo River, low water, 853; high water (1881), 873; extreme high water (of Red River), about 882; grade	255·2	884
Georgetown	255·6	884
Perley	262·3	877
Hendrum	268·3	875
Wild Rice River, low water, 836; high water (1881), 858; grade	270·0	872
Halstad	274·4	870

GREAT NORTHERN RAILWAY SYSTEM—Continued.

FROM WAHPETON BY CASSELTON, MAYVILLE, LARIMORE, AND PARK RIVER, TO LANGDON.

The profile agrees with connecting railways and other branches of this system at Davenport, Everest, Casselton, Portland Junction, and Larimore. Leveling for the survey of the beaches of Lake Agassiz, from Park River and Walhalla northward, is also found to agree with the Canadian Pacific Railway at Thornhill.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Wahpeton	215·7	965
Junction with main line by Breckenridge and Moorhead to Neche	216·7	963
Wild Rice River, water, 936; grade	219·9	953
Antelope Creek, water, 931; grade	222·2	954
Dwight	222·7	954
Barrett	231·4	953
Colfax	235·7	960
Walcott	241·8	960
Sheyenne River, water, 930; grade	248·3	948
Kindred	249·7	942
Davenport, crossing the Fargo and Southwestern (Northern Pacific) Railroad	254·8	923
Addison	258·5	917
Maple River, water, 904; grade	262·1	920
Durbin	262·6	918
Dry Run, bed, 910; grade	263·6	920
Everest, junction of line to Ripon and Portland	267·6	935
Casselton, crossing the Northern Pacific Railroad	270·6	938
Amenia	277·8	954
Rush River, bed, 945; grade	279·5	957
(An ice gorge below this bridge April 4, 1882, raised the water above the track at Amenia.)		
Arthur	284·7	992
South Fork of Elm River, bed, 962; grade	290·4	980
Hunter	290·7	980
Greenfield	296·5	948
North Fork of Elm River, bed, 927; grade	301·1	947
Blanchard	301·4	947
Murray	307·7	960
Goose River, bed, 924; water, held by dam, 936; grade	312·5	954
Mayville	313·5	978
Portland Junction, line from Ripon and Portland	318·3	1009
Hatton	325·0	1085
Northwood	333·3	1119
Kempton	339·7	1127
Junction with line from Grand Forks to Great Falls	345·5	1130
Larimore	345·9	1134
Park River Junction, with line to Great Falls	348·3	1133
South Branch of Turtle River, bed, 1,109; grade	349·9	1127
McCanna	354·0	1140
North Branch of Turtle River, bed, 1,115; grade	356·7	1132
Summit, natural surface and grade	358·3	1164
Orr's	360·5	1098
Inkster	364·8	1036
McCauleyville Beach of Lake Agassiz, crest, 996; grade	366·3	991
(This beach ridge is about 30 rods wide; the descent from its crest is 5 feet to the south and 8 feet to the north.)		
Forest River, bed, 941; grade	366·6	980
Conway	370·9	988
McCauleyville Beach, crest, 996; grade	374·3	998
(Along the greater part of its course for the next 8 miles to Park River, the railway is built on this beach ridge.)		
Park River Station	382·3	998

GREAT NORTHERN RAILWAY SYSTEM—Continued.

FROM WAHPETON TO LANGDON—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
South Branch of Park River, bed, 964; grade	382·9	996
Small stream, bed, 1,087; grade	386·5	1107
Beach of Lake Agassiz, crest, 1,128; grade	387·2	1129
(This beach ridge has a width of 25 rods, with a descent of 4 or 5 feet from its crest to its base on each side.)		
Beach, crest, 1,155; grade	388·3	1156
(From the crest there is a descent of 16 feet in a quarter of a mile southeastward along the railway, and of 2 feet in 15 rods northwestward.)		
Beach, crest, 1,163; grade	388·45	1161
(The descent to the east is 10 feet in 25 rods, and to the west 3 feet in 15 rods.)		
Edinburgh	391·7	1189
Small stream, bed, 1,182; grade	392·3	1191
Middle Branch of Park River, bed, 1,242; water, 1,243; grade	395·1	1278
Water course tributary to the Middle Branch, bed, 1,298; grade	396·9	1352
Second water course tributary to the Middle Branch, bed, 1,327; grade	398·2	1409
Another water course tributary to the Middle Branch, bed, 1,479; grade	400·6	1507
Top of steep westwardly ascending grade (1 foot above the natural surface)	402·6	1579
Milton	404·2	1586
Water course tributary to the North Branch of Park River, bed, 1,586; grade	406·5	1594
Osnabrock	410·0	1620
Summit, natural surface and grade	414·7	1659
Langdon	421·6	1610
Pembina River at the bridge a half mile east of Walhalla (determined by survey from Park River), low and high water, 934–943; proposed grade of railway bridge, 953 feet.)		

FROM EVEREST AND RIPON TO PORTLAND.

This agrees with the Northern Pacific Railroad, and with the line through Casselton and Mayville at Portland Junction.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Everest, junction with the Mayville line	267·6	935
Crossing the Northern Pacific Railroad	271·8	954
Campbell Beach of Lake Agassiz, crest, 994; grade	274·3	989
Ripon	278·0	1040
Junction of the Hope Branch	278·2	1046
Swan Creek, bed, 1,049; grade	280·5	1070
Creek, bed, 1,067; grade	284·3	1091
Tank and section house, grade	286·3	1094
Rush River, bed, 1,074; grade	286·5	1098
Erie	288·3	1126
Summit, grade	289·5	1131
South Branch of North Fork of Elm River, bed, 1,062; grade	295·8	1081
Depression, grade	296·3	1079
Summit, grade	296·9	1089
Line of Cass and Traill Counties, grade	297·1	1087

GREAT NORTHERN RAILWAY SYSTEM—Continued.

FROM EVEREST AND RIPON TO PORTLAND—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Galesburg	299·1	1079
North Branch of North Fork of Elm River, bed, 1,063; grade	299·7	1076
Clifford	304·2	1055
Roseville	310·4	1009
Portland	314·7	983
Goose River, bed, 933; water, 936; grade	315·6	975
Portland Junction, 318·3 miles from St. Paul by way of Mayville	319·1	1009

HOPE BRANCH.

Junction near Ripon	278·2	1046
Tank, grade	278·8	1065
Absaraka	279·3	1080
Upper or Herman Beach of Lake Agassiz, crest, 1,097; grade	279·8	1096
Swan Creek, bed, 1,078; grade	280·9	1111
Ayr (formerly Elgin)	285·1	1200
Summit, cutting 3 feet; grade	288·6	1236
Page City	294·2	1175
Colgate	301·2	1177
Hope	307·6	1241

MAIN LINE FROM DULUTH, BY HINCKLEY, ST. CLOUD, AND WILLMAR, TO SIOUX FALLS.

[The portion from Duluth to Hinckley is operated under a lease from the Eastern Railway Company of Minnesota; and the portion beyond Willmar under a lease from the Willmar and Sioux Falls Railway Company.]

The profile from Duluth to Hinckley is in two series of leveling, which meet half way between these points. Referring the northeastern part to sea level by the known height of Lake Superior, the elevations thence derived for the southwestern part of the profile are 8 feet lower than those of the St. Paul and Duluth Railroad at Hinckley. The latter, however, seems to be reliable, and the southwest half of this profile (at Willow River and thence to Hinckley) is therefore made to agree with the St. Paul and Duluth Railroad. The discrepancy of 8 feet is all placed thus at the point of connection of the two separate series of leveling, their difference being taken as 437 feet instead of the 429 feet stated by the profile.

From Hinckley to St. Cloud the original figures of the profile (obtained by leveling independent of the foregoing) receive here a uniform addition of 13 feet, to agree with the St. Cloud and Fergus Falls division of this railway system and the St. Paul and Northern Pacific Railroad at St. Cloud and East St. Cloud, and with the Princeton Branch at Milaca Junction; but only an addition of 11 feet is made to this profile at Hinckley for accord with the St. Paul and Duluth Railroad.

The profile from St. Cloud to Willmar agrees with the Minneapolis and Pacific Railway at Paynesville, and with the Breckenridge division at Willmar; and the profile of the Willmar and Sioux Falls Railway agrees with intersecting railways at Granite Falls, Hanley Falls, Marshall, Pipestone, and Sioux Falls.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Duluth	0·0	607
Lake Superior, mean	1·0–2·0	602
West Superior	2·6	631
Boylston	10·3	687
Nemadji River, water, 620; grade	12·6	711

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE FROM DULUTH TO SIOUX FALLS—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Dedham	17·2	802
West Balsam Creek, bed, 824; grade	20·6	872
Boundary between Wisconsin and Minnesota, grade	23·0	929
Foxboro	24·2	956
East Fork of Net River, bed, 924; grade	26·7	1002
Net River, bed, 968; grade	28·6	1042
(The Norway Hills, consisting of morainic and kame-like drift, are crossed from 29·1 to 33·3 miles, having along the line of this survey crests 10 to 40 feet above the depressions, while the height of the crests above the sea level rises in this distance from 1,065 to 1,160 feet.)		
Holyoke	33·4	1141
Willow River, bed, 1,142; grade	38·8	1153
Kerrick	39·2	1155
Mansfield	47·2	1156
Summit, cutting 15 feet; grade	51·1	1220
Partridge	55·6	1166
Kettle River (near Sandstone, between the Upper and Lower Falls), ordinary stage of water, 955; grade	61·0	988
Wareham	63·7	1082
Summit, cutting 12 feet; grade	65·3	1098
Grindstone River, water, 1,007; grade	70·2	1032
Hinckley	70·4	1032
Same, crossing the St. Paul and Duluth Railroad	70·8	1032
Little Pokegama Creek, water, 1,011; grade	75·3	1024
Pokegama	77·8	1028
Pokegama Creek, water, 1,011; grade	78·5	1023
Mud Creek, water, 1,001; grade	83·4	1013
Snake River, water, 945; grade	91·2	979
Ann River, water, 958; grade	92·8	999
North Branch of Ground House River, water, 1,021; grade	97·1	1037
Ground House	97·5	1040
South Branch of Ground House River, water, 1,016; grade	101·8	1046
Bogus Brook, water, 1,041; grade	104·2	1074
Milaca	109·7	1072
Rum River (East Branch), bed, 1,036; water, 1,042; grade	110·2	1066
Milaca, junction of the Princeton Branch	110·3	1070
West Branch of Rum River, water, 1,056; grade	112·4	1076
Bridgeman	113·0	1092
Estes Brook Station	115·9	1109
Estes Brook, water, 1,090; grade	116·3	1100
Oak Park	119·0	1130
St. Francis River, water, 1,103; grade	120·6	1110
Creek, water, 1,106; grade	121·2	1111
St. Francis	121·4	1115
Rice Creek, water, 1,118; grade	123·6	1130
Foley	123·8	1132
Parent	128·0	1120
Elk River, water, 1,014; grade	130·2	1043
Former water course, extending from the Mississippi River at Sauk Rapids southeasterly to the Elk River, natural surface	136·2–136·8	1021–1024
Crossing the St. Paul and Northern Pacific Railroad	137·2	1025
Mississippi River, water held by dam, 975; grade	137·7	1032
St. Cloud, 74·6 miles from St. Paul	138·1	1037
St. Cloud, junction of line to Fergus Falls	140·0	1048
O'Brien	142·0	1078
Rockville	149·3	1075
Sauk River, bed, 1,070; water, 1,075; water above the dam, 1,082; grade	153·6	1091

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE FROM DULUTH TO SIOUX FALLS—Continued.

	From Duluth.	Above the
	Miles.	*Feet.*
Cold Springs	153·9	
Creek, bed, 1,084; grade	156·9	
Richmond	158·2	
Sauk River, bed, 1,078; ordinary low water, 1,083; grade.	158·8	
Summit, natural surface and grade	159·6	
Depression, natural surface, swampy, 1,087–1,089; grade.	160·9–161·5	
Roscoe	164·7	
Paynesville	169·9	
Crossing the Minneapolis and Pacific Railway	170·8	
North Fork of Crow River, bed, 1,165; water, 1,166; bottom land, 1,172; grade	171·5	
Hawick	175·4	
Summit, cutting 2 feet; grade	176·0	
Outlet of Long Lake, bed, 1,205; grade	178·6	
Summit, cutting 6 feet; grade	179·2	
New London	181·9	
Middle Fork of Crow River, mill-pond, level with Nest Lake, water, 1,162; grade	184·1	
Green Lake, water	184·1	
Spicer	186·3	
Water course tributary to Green Lake, bed, 1,157; grade.	186·6	
Water course tributary to Eagle Lake, bed, 1,133; grade.	190·2	
Summit, cutting 10 feet; grade	192·5	
Willmar Junction, Breckenridge line	195·1	
Willmar, 102·5 miles from St. Paul	196·3	
Junction, leaving the Breckenridge line	196·8	
Raymond	208·3	
Clara City	215·9	
Maynard	221·8	
Minnesota River, water, 910; grade	230·0	
Granite Falls	230·8	
Crossing the Minneapolis and St. Louis Railway	240·5	
Hanley Falls	240·6	
Cottonwood	246·7	
Three Mile Creek, bed, 1,080; grade	253·1	
Green Valley	254·0	
Crossing the Winona and St. Peter division of the Chicago and Northwestern Railway	259·1	
Marshall	259·2	
Lynd	265·9	
(Very uneven morainic contour, with elevations 20 to 80 feet above the depressions, is crossed by this railway from Lynd to Russell.)		
Russell	272·2	
Dakota Central division of the Chicago and Northwestern Railway, its grade	277·2	
This railway goes over the preceding; grade on bridge..	277·2	
Florence	280·1	
Ruthven	285·2	
Summit, cutting 2 feet; grade (highest in crossing the Coteau des Prairies)	288·7	
Holland (a summit of grade)	293·0	
Crossing the Burlington, Cedar Rapids and Northern, and Chicago, St. Paul, Minneapolis and Omaha Railways	301·6	
Crossing the Chicago, Milwaukee and St. Paul Railway.	301·7	
Pipestone	301·8	
Ihlen	308·5	
Split Rock Creek, low and high water, 1,623–1,627; grade.	309·0	
Same, water, 1,536; grade	313·0	

GREAT NORTHERN RAILWAY SYSTEM—Continued.

MAIN LINE FROM DULUTH TO SIOUX FALLS—Continued.

	From Duluth.	Above the sea.
	Miles.	*Feet.*
Jasper (on the line between Pipestone and Rock Counties)	313·2	1545
Split Rock Creek, water, 1,504; grade	316·7	1520
Same, water, 1,495; grade	318·1	1513
Line between Minnesota and South Dakota, grade	319·4	1510
Sherman	320·8	1496
Split Rock Creek, low and high water, 1,476–1,484; grade	321·3	1495
Devil's Gulch, water, 1,455; grade	323·7	1501
Split Rock Creek, low and high water, 1,430–1,445; grade	325·3	1465
Palisades	326·1	1457
Split Rock Creek, water, 1,313; grade	331·5	1346
Corson	332·4	1362
Big Sioux River, low and high water in ordinary years, 1,290–1,298; extreme high water, about 1,307; grade	336·0	1311
Crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	338·6	1323
Crossing the Illinois Central Railroad	342·0	1389
Crossing the Chicago, Milwaukee and St. Paul Railway	342·6	1404
Big Sioux River, above the upper dam of Sioux Falls, low and high water, 1,383–1,388; grade	342·7	1407
Crossing the Burlington, Cedar Rapids and Northern Railway	342·8	1410
Sioux Falls	343·2	1420
End of track-laying October 26, 1888	343·5	1425

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM.

[From profiles in the office of George H. White and M. D. Rhame, engineers, Minneapolis; and in part from manuscript and profiles furnished by George B. Woodworth, assistant engineer, Milwaukee.]

ST. PAUL TO MINNEAPOLIS, SHORT LINE.

Referred to sea level by the elevation of the Mississippi River at St. Paul, determined by United States engineers; and agreeing at Minneapolis with the St. Paul and Northern Pacific, and the St. Paul, Minneapolis and Manitoba Railways.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, extreme low and high water of the Mississippi River	0·0	683–702
St. Paul, union depot	0·0	703
Chestnut Street Station	0·8	709
Summit, cutting 12 feet; grade	4·8	937
Merriam Park	5·8	908
Mississippi River, bed, 702; ice (1879), 709; high water, 724; top of rock in east river bluff, 799; crest of river bluff, 828; grade	7·3	843
Short Line Junction	9·0	842
Minneapolis, depot of this railway, Washington avenue S., opposite Fourth avenue	10·8	826

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

ST. PAUL TO MINNEAPOLIS, BY FORT SNELLING.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul	0·0	703
Mendota, junction with the Chicago, St. Paul, Minneapolis and Omaha Railway	5·6	722
Bridge crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	6·0	738
St. Paul Junction, Mendota, with line to Austin and McGregor	6·4	760
Minnesota River, bed, 672; low water, 688; high water, 710; grade	7·0	718
Fort Snelling Station	7·2	722
(The fort is about 75 feet higher on the crest of the river bluff.)		
Minnehaha	9·6	813
Minnehaha Creek, bed, 802; water, 803; grade	9·7	816
Minnehaha Falls, 50 feet	9·7	800–750
Short Line Junction	13·0	842
Minneapolis	14·8	826

HASTINGS TO BENTON JUNCTION.

Referred to sea level at Hastings by the elevation of the Mississippi River, determined by United States engineers; and agreeing with connecting railways at Farmington, Shakopee, Chaska, and Benton Junction.

	From Hastings.	Above the sea.
	Miles.	*Feet.*
Hastings, extreme low water of the Mississippi River, 670·5; high water (1880), 687·3; extreme high water (1881), about 690	0·0	670·5–690
Hastings, junction with the River division	0·0	707
Top of ascending grade, at edge of prairie in Sec. 5, Marshan, natural surface and grade the same	3·0	825
Vermilion, about	8·1	825
Auburn	11·9	860
Farmington, crossing the Iowa and Minnesota division	17·5	902
Lakeville (Fairfield)	22·3	941
Summit, close west of the line between Dakota and Scott Counties, Minn., cutting 10 feet; grade	26·5	1081
Summit, cutting 12 feet; grade	32·8	959
Prior Lake Station	33·1	947
Prior Lake, bed, 882; water	33·7	907
Cut, 27 feet deep; grade	34·2	937
Cut, 25 feet deep; grade	36·1	901
Shakopee, crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	41·5	753
Minnesota River, bed, 668; low water, 690; high water, 717; grade	44·5	725
Chaska	45·4	726
Crossing the Minneapolis and St. Louis Railway	45·5	728
Carver	47·5	813
Bridge over road and ravine, bed of ravine, 747; grade	47·8	816
Dahlgren	50·9	980
Summit, cutting 6 feet; grade	51·4	981
Carver Creek, bed, 906; grade	52·3	928
Benton Junction, of line from Minneapolis to Aberdeen	53·7	942

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

HASTINGS AND DAKOTA DIVISION, MAIN LINE.

[Minneapolis to Ortonville and Aberdeen, with continuation of this line to Bowdle.]

This agrees with connecting railways at Benton Junction, Norwood, Appleton, Ortonville, Groton, and Aberdeen.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis	0·0	826
Short Line Junction	1·8	842
Summit, grade	4·8	880
Neck of land between the Lake of the Isles and Lake Calhoun, natural surface, 856; grade	5·4	859
West Minneapolis Transfer, at Bass Lake, grade	6·9	884
Bass Lake, water	[illegible]	878
Summit, cutting 17 feet; grade	8·2	913
Depression, filling 10 feet; grade	8·5	899
Hopkins Station, cutting 12 feet; grade	8·9	911
Minnehaha Creek, bed, 893; grade	9·1	910
Shady Oak Lake, bed, 869; water, 905; grade	12·2	909
Crossing the Minneapolis and St. Louis Railway	13·2	921
Island Lake, water, 892; grade	14·5	897
Purgatory Creek, bed, 838; grade	15·3	900
Duck Lake, water, 910; grade	15·8	920
Chanhassen	18·4	965
Lake Hazeltine, water, 917; grade	21·7	922
Hazeltine	21·9	928
Chaska Creek, bed, 893; water, 895; grade	22 6	936
Augusta	27·1	978
Lake Aue, bed, 912; water, 942; grade	28·6	945
Carver Creek, bed, 909; water, 911; grade	29·9	921
Benton Junction, of line from Hastings	30·7	942
Cologne	32·6	945
Summit, cutting 9 feet; grade	37·0	989
Crossing the Pacific division of the Minneapolis and St. Louis Railway	39·4	972
Norwood	39·9	988
Tiger Lake, water	41·4	977
Summit, ¼ mile east of the line between Carver and McLeod Counties, cutting 6 feet; grade	43·4	1002
Buffalo Creek; bed, 964; grade	46·4	981
Summit, cutting 5 feet; grade	50·7	1019
Glencoe	51·2	1006
Peat marsh, grade	53·0	1027
Summit, cutting 3 feet; grade	53·5	1033
Sumter	57·0	1035
Depression, grade	59·0	1012
Summit, grade	60·3	1036
Gravel pits, grade	61·0	1020
Buffalo Creek, water, 1,005; grade	61·2	1019
Brownton	61·4	1024
Summit, cutting 10 feet; grade	61·6	1026
Lake Addie, water, 1,007; grade	61·9	1019
Summit, grade	64·1	1057
Depression, grade	64·4	1049
Summit, cutting 3 feet; grade	67·8	1074
Stewart	68·1	1064
Depression, grade	69·1	1057
Summit, grade	70·1	1076
Near McLaughlin's Lake, grade	71·6	1064
Creek, bed, 1,060; grade	73·2	1066
Summit, highest between Hastings and Ortonville; grade	77·4	1093
South Fork of Buffalo Creek, bed, 1,067; grade	78·5	1082
Hector	79·5	1081
Summit, grade	80·8	1091
Bird Island	88·5	1089
Olivia	93·1	1082

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

HASTINGS AND DAKOTA DIVISION—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
East Fork of Beaver Creek, bed, 1,066; grade	93·6	1073
West Fork of Beaver Creek, bed, 1,051; grade	100·8	1057
Renville	104·3	1064
Sacred Heart	111·2	1061
Hawk Creek, water, 963; top of bluff west of creek, 1,041; grade	116·4	1017
East line of Chippewa County, grade	117·8	1047
Minnesota Falls	118 4	1011
Granite Falls	120·4	941
Palmer's Creek, grade	122·8	921
Myer's Station and Brofee's Creek, grade	128·4	932
Rock cut, 10 feet deep; grade	131·8	948
Montevideo	133·8	927
Chippewa River, water, 913; grade	134·0	930
Top of bluff, grade	136·6	1009
Watson	140·1	1029
Beginning of descent westward	141·3	1028
Depression, level grade	144·1–144·6	937
Top of ascending grade	146·3	993
Milan	149·1	995
Two miles farther northwest, grade	151·1	1019
Summit, grade	154·5	1035
Appleton Station, and crossing the Watertown and Huron Branch of the St. Paul, Minneapolis and Manitoba Railway	157·3	1007
Pomme de Terre River, water, 978; grade	157·6	1007
(This railway is straight from 158·6 miles to Odessa, a distance of 14 miles.)		
East line of Big Stone County, grade	161·4	987
Correll	164·1	980
Summit, level grade	165·4–166·5	985
Odessa	172·6	963
Stony Run, water, 958; grade	173·3	965
Summit, grade	177·2	1002
Junction of the Fargo and Southern Railway, and of spur to Ortonville	177·9	997
Ortonville (on spur, 1·2 miles from main line)	179·1	990
Minnesota River, bed, 962; grade	178·6	972
Big Stone Lake, low and high water, 962–967; ordinary stage of water	179·5	963
Big Stone City	179·5	979
Whetstone River beside this railway, water, 973; grade	180·0	1003
Cut, 48 feet deep; grade	180·1	1005
Whetstone River, bed, 998; water, 1,005; grade	180·8	1025
Milbank, junction of the Whetstone Branch	189·9	1148
Foot of the Coteau des Prairies, near Twin Brooks Station	198·0	1294
Marvin	205·0	1657
West line of Grant County, grade	210·7	1939
Summit Station, on the crest of the Coteau des Prairies, cutting 3 feet, highest grade on this line	212·3	2000
Depression, filling 7 feet; grade	214·9	1939
Summit, natural surface and grade	217·5	1961
Waubay	225·7	1813
Depression, filling 9 feet; grade	228·7	1803
Summit, cutting 7 feet; grade	233·6	1849
Depression, filling 11 feet; grade	235·5	1819
Webster	236·2	1842
Summit, cutting 6 feet; grade	236·6	1848
Bristol, junction of line to Madison	247·6	1775
Andover, junction of the Harlem Branch	257·6	1476
Foot of descending grade, filling 3 feet	261·7	1349
Groton, near junction with branch of the Chicago and Northwestern Railway	267·3	1304

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

HASTINGS AND DAKOTA DIVISION—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
James River, bed, 1,267; water, 1,269; top of river bank, 1,277; grade	275·0	1282
Bath	278·4	1301
Moccasin Creek, bed, 1,284; grade	285·1	1295
Crossing the Chicago and Northwestern Railway	285·8	1300
Aberdeen, junction with the James River division	286·4	1300
Mina	299·5	1432
Ipswich	312·7	1530
Roscoe, junction of branches to Orient and Eureka	328·0	1826
Summit, grade	340·9	2017
Bowdle	343·2	1995

ORTONVILLE TO FARGO (FARGO AND SOUTHERN RAILWAY).

This agrees with connecting railways at Graceville, Sewall, Wahpeton, and Fargo.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Junction with the Hastings and Dakota division, main line, near Ortonville	177·9	997
Top of continuous ascent from the junction; grade	180·9	1110
Rupert	187·2	1136
Batavia	190·1	1163
Summit, natural surface and grade	191·5	1187
Tokua Lake, water, 1,091; grade	197·1	1103
Graceville	197·9	1111
Crossing the Brown's Valley Branch of the St. Paul, Minneapolis and Manitoba Railway	198·3	1112
Ravine, bed, 1,044; grade	204·4	1052
Dumont	208·2	1048
Wheaton	215·3	1018
Mustinka River, bed, 977; grade	215·9	993
Summit, cutting 10 feet in gravel and sand, a delta of Lake Agassiz, grade	220·7	1036
Bois des Sioux River, bed, 966; ordinary low water, 968; grade	224·2	975
White Rock	224·4	973
Sewall (Fairmount)	234·2	983
Crossing the Minneapolis and Pacific Railway	234·5	985
Crossing the St. Paul, Minneapolis and Manitoba Railway	235·0	985
Tyler	240·6	969
Wahpeton, crossing the Northern Pacific, Fergus and Black Hills Railroad	248·4	965
Same, crossing the St. Paul, Minneapolis and Manitoba Railway	248·6	965
Wahpeton depot	248·8	964
Woodhull	256·0	952
Abercrombie	262·9	935
Christine	272·6	928
Hickson	279·2	917
Wild Rice Station	284·6	911
Wild Rice River, bed, 881; grade	285·1	911
Saunders	288·4	907
Rose Creek, bed, 882; grade	289·3	906
Big Slough, bottom, 897–894; grade (level to crossing of the Northern Pacific Railroad)	293·0–294·2	905
Fargo	294·9	903

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

WHETSTONE BRANCH.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Milbank, junction with the Hastings and Dakota division, main line	189·9	1148
South Branch of Whetstone River, bed, 1,130; grade	190·7	1147
Middle Branch of Whetstone River, bed, 1,131; grade	194·1	1145
Corona	200·0	1173
North Branch of Whetstone River, bed, 1,166; grade	204·6	1181
Wilmot (a summit of grade, cutting 3 feet)	206·8	1196
Depression, filling 8 feet; grade	208·2	1168
Summit, cutting 7 feet; grade	212·7	1201
Depression (South Branch of the Minnesota River), filling 6 feet; grade	215·1	1179
Summit, natural surface and grade	222·7	1221
(This summit is 60 rods south from the end of the track.)		

RIVER DIVISION, AND PART OF THE DUBUQUE DIVISION, MAIN LINE, ST. PAUL TO LA CROSSE AND NORTH McGREGOR.

This agrees with connecting railways and other divisions and branches of this system, and with the elevations of the Mississippi River, determined by United States engineers, at Hastings, Cannon Junction, Wabasha, Winona, La Crosse, and North McGregor.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis, depot of this railway, Washington avenue S., opposite Fourth avenue	0·0	826
St. Paul, union depot	10·8	703
Dayton's Bluff Station	12·2	707
Newport	18·9	749
Langdon	24·3	811
St. Croix Junction, Stillwater Branch	29·7	694
Mississippi River, bed, 657; extreme low water, 669; ordinary stage, 673; extreme high water, 690; grade	30·2	704
Hastings (a summit of grade), junction of the Hastings and Dakota division	30·5	707
Vermilion River, water, 675; grade	31·7	693
Etter	39·0	689
Eggleston	43·6	689
Cannon Junction, Cannon Falls line	47·5	692
Cannon River, water, 677; grade	47·8	691
Red Wing	51·5	685
(Zero of Red Wing city levels, at low water of the Mississippi River in 1859, 668 feet above mean sea level.)		
Wacouta	57·4	706
Frontenac	62·1	718
Lake City	68·4	703
Minnie (or Collins) Creek, water, 670; grade	69·9	697
Conway Creek, water, 671; grade	70·9	691
(Lake Pepin, extending from Wacouta to Read's Landing, extreme low water, 664; extreme high water, 680·5.)		
Read's Landing	79·0	681
Mississippi River here, extreme low and high water	79·0	663·7–680·5
Read's Junction, Chippowa Valley and Superior division	79·8	686
Wabasha (a summit of grade)	81·1	711

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

RIVER DIVISION, ETC.—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Midland Junction, crossing the line to Zumbrota (Wabasha division)	86·2	694
Zumbro River, water, 682; grade	86·8	693
Kellogg	87·2	701
Weaver	94·7	672
Minneiska	97·7	670
Mount Vernon	99·4	673
Whitman	103·2	678
Minnesota City	108·0	675
Mississippi River here, extreme low and high water	108·0	643–662·4
St. Peter Junction, crossing the Chicago and Northwestern Railway	112·8	674
Winona	114·1	660
Homer	118·5	661
Lamoille	123·1	658
Richmond	127·5	672
Dakota	131·8	655
Dresbach	132·8	674
River Junction, with the Southern Minnesota division	137·5	643
On line to La Crosse:		
Junction with the Southern Minnesota division, near the west end of the bridge	138·9	655
La Crosse Bridge, extreme low and high water of the Mississippi River	139·3	628–643·5
On line from River Junction southward:		
La Crescent	138·6	649
Southern Minnesota Junction, Dubuque and Southern Minnesota divisions	140·9	643
Brownsville	148·4	641
Caledonia Junction, Preston Branch	155·3	639
New Albin	162·8	648
Lansing	174·2	632
Heytman's	181·7	634
Harper's Ferry	189·5	646
Waukon Junction, Waukon Branch	193·3	631
North McGregor, junction with the Iowa and Dakota Division	201·0	625
Mississippi River here, low and high water	201·0	604–626

STILLWATER BRANCH.

Agreeing with connecting railways at Stillwater.

	From Hastings.	Above the sea.
	Miles.	*Feet.*
St. Croix Junction, River division, 29·7 miles from Minneapolis	0·8	694
Point Douglas	3·0	709
Straight Cooley, grade	8·8	700
Trout Brook, grade	11·3	699
Afton	14·6	695
Lakeland	17·6	742
Baytown (South Stillwater)	22·4	694
Stillwater	25·7	694

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

CANNON FALLS LINE, RED WING TO NORTHFIELD.

This agrees at Cannon Junction, Randolph, and Northfield.

	From Red Wing.	Above the sea.
	Miles.	*Feet.*
Red Wing	0·0	685
Cannon Junction, River division	4·0	692
Crossing slough, bottom, 675; grade	4·2	684
Deep cut, grade	9·7	730
Welch	11·5	719
Cannon River, bed, 732; grade	15·4	752
Same, bed, 736; grade	15·6	755
Summit, grade	18·3	821
Creek, bed, 771; grade	18·6	817
Pine Creek, bed, 766; grade	19·4	780
Cannon Falls	21·4	816
Paxton's Glen, grade	22·5	841
Crossing the Chicago, St. Paul and Kansas City Railway, Randolph	27·0	876
Chub Creek, bed, 859; water, 864; grade	27·4	877
Waterford	33·9	902
Crossing the Wisconsin, Minnesota and Pacific (Minneapolis and St. Louis) Railway	35·4	912
Northfield, junction with the main line of the Iowa and Minnesota division	36·0	916

WABASHA DIVISION, WABASHA TO ZUMBROTA.

This agrees with the Chicago and Northwestern Railway at Zumbrota.

	From Wabasha.	Above the sea.
	Miles.	*Feet.*
Wabasha	0·0	711
East Wabasha	1·0	680
Midland Junction, crossing the River division	6·1	694
Glasgow	12·8	715
McCracken	17·7	731
Theilman	20·3	742
Lakey	23·3	755
Keegan	25·2	758
Millville	29·1	786
Jarrett	31·7	791
Hammond	34·3	804
Funk	37·7	819
Zumbro Falls	41·8	835
Summit, grade	47·8	894
Depression, grade	49·0	867
Bright's	49·2	871
Mazeppa	52·2	934
Forest Mills	58·4	969
Summit, grade	59·8	985
Zumbrota	60.0	979

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

CHIPPEWA VALLEY AND SUPERIOR DIVISION, WABASHA TO EAU CLAIRE.

Referred to sea level at Wabasha by connection with the River division; and agreeing there with the elevation of the Mississippi River determined by United States engineers, and at Eau Claire with the Chicago, St. Paul, Minneapolis and Omaha Railway.

	From Wabasha.	Above the sea.
	Miles.	*Feet.*
Wabasha	0·0	711
Read's Junction, River division	1·3	686
Mississippi River at mouth of the Chippewa River, low water (1864), 663; high water (1880), 682; grade	1·6	686
Trevino	3·3	680
Plumer's Mill	5·6	684
Maxwell	11·4	698
Chippewa River here, high water (1880)	11·4	696
Beef Slough, high water (1880), 703; grade	14·1	712
Round Hill Station	15·8	736
Durand	18·5	724
Red Cedar	24·7	759
Red Cedar Junction, Menomonie Branch	25·7	729
Tyrone	27·4	729
Meridian	32·4	746
Caryville	36·9	758
Porter's Mills	43·2	769
Chippewa River, grade	46·3	785
Shawtown	46·5	777
Chippewa River, high water, 780; grade	47·8	790
Eau Claire	48·0	788
Crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	48·8	828
Central Transfer, junction with the Wisconsin Central Railroad	49·8	900

MENOMONIE BRANCH.

Red Cedar Junction, with the foregoing	25·7	729
Chippewa River near the mouth of Red Cedar River, high water (1880), 728; grade	26·1	736
Dunnville	27·7	731
Downsville	32·4	754
Red Cedar River, high water, 758; grade	32·9	765
Menomonie	41·2	805
Cedar Falls	46·2	867

PRESTON BRANCH.

	From Caledonia Junction.	Above the sea.
	Miles.	*Feet.*
Caledonia Junction, Dubuque Division, main line, 155·3 miles from Minneapolis	0·0	639
Freeburg	6·0	659
Foot of westward ascent	12·0	971
Caledonia	14·0	1179
Spring Grove	23·8	1324
New House	29·0	1194
Mabel	32·3	1117
Donald Switch	37·0	1354
Canton	41·2	1330
Harmony (a summit of grade)	46·6	1339
Root River, water, 905; grade	57·0	920
Preston	58·0	922

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continue

IOWA AND MINNESOTA DIVISION, MAIN LINE, MINNEAPOLIS AND ST. PAU AUSTIN AND CALMAR.

This agrees with connecting railways and other divisions and branches of system at St. Paul Junction, Farmington, Northfield, Faribault, Owatonna, Ran Austin, Taopi, Conover, and Calmar.

	From Minneapolis.	Above th
	Miles.	*Feet.*
Minneapolis	0·0	
St. Paul Junction, Mendota, 6·4 miles from St. Paul	8·4	
Summit, cutting 5 feet; grade	15·0	
Westcott	16·0	
At a lake 2 miles south; grade	18·0	
Summit, grade	20·0	
At Keegan's Lake, grade	20·5	
Rosemount	22·1	
Vermilion River, water, 890; grade	28·9	
Farmington, crossing the Hastings and Dakota division	29·1	
Farmington depot	29·3	
Summit, cutting 11 feet; grade	32·6	
Castle Rock	36·1	
(The height of "Castle Rock" above the adjoining surface is 44 feet; of its slender portion above the broader pedestal, 19 feet.)		
Chub Creek, water, 918; grade	37·8	
Summit, cutting 12 feet; grade	40·8	
Northfield, junction with the Cannon Falls line	42·2	
Heath Creek, water, 906; grade	43·3	
Dundas	45·3	
Wolf Creek, water, 948; grade	46·4	
Summit, cutting 9 feet; grade	50·0	
Depression, grade	50·8	
Summit, cutting 30 feet; grade	53·6	
Cannon River, water, 960; grade	55·0	
Crossing the Wisconsin, Minnesota and Pacific (Minneapolis and St. Louis) Railway	55·2	
Faribault	55·8	
Summit, cutting 4 feet; grade	58·5	
Summit, cutting 14 feet; grade	61·2	
Straight River, low and high water, 1,070–1,086; grade	64·8	
Medford	65·1	
Clinton Falls	66·9	
Maple Creek, water, 1,118; grade	70·3	
Owatonna depot and crossing the Winona and St. Peter division of the Chicago and Northwestern Railway	71·0	
Summit, grade	74·7	
Pratt	76·2	
Aurora	79·7	
Turtle Creek, water, 1,240; grade	80·2	
Bixby	82·9	
Summit, grade	86·5	
Blooming Prairie	88·9	
Madison	94·5	
Lansing	98·1	
Ramsey, crossing the Southern Minnesota division	100·6	
Red Cedar River, bed, 1,186; water, 1,191; grade	101·0	
Wolf Creek, bed, 1,182; grade	102·2	
Austin	103·6	
Dobbin's Creek, bed, 1,177; water, 1,181; grade	103·9	
Austin Junction, Austin and Mason City line	104·1	
Rose Creek, bed, 1,228; grade	111·4	
Rose Creek Station	111·8	
Summit, cutting 7 feet; grade	115·2	
Little Cedar River, water, 1,258; grade	116·0	
Creek, bed, 1,265; grade	117·9	

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

IOWA AND MINNESOTA DIVISION—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Adams	118·2	1282
Summit, cutting 2 feet; grade	121·1	1349
Taopi, near crossing of the Chicago, St. Paul and Kansas City Railway	121·9	1349
Creek, bed, 1,276; grade	127·1	1291
Creek, bed, 1,274; grade	127·6	1291
Summit, cutting 5 feet; grade	128·4	1306
Le Roy	129·9	1285
State line, natural surface and grade	130·4	1269
Staff Creek, water, 1,231; grade	134·1	1242
Chester	137·4	1232
Beaver Creek, water, 1,193; grade	141·0	1203
Cut 19 feet deep; grade	142·2	1245
Lime Springs	142·4	1246
Summit, cutting 7 feet; grade	144·6	1298
Head of Turkey River, bed, 1,263; grade	147·0	1270
Bonair (a summit of grade)	147·5	1309
Depression, grade	151·0	1269
Cresco	153·5	1300
Depression, level grade	154·7–155·7	1283
Summit, natural surface and grade	156·5	1300
Depression, filling 21 feet; grade	164·9	1190
Conover, junction of the Decorah Branch	169·5	1235
Summit, natural surface and grade	171·6	1288
Calmar, junction with the Iowa and Dakota division, 42 miles from North McGregor	172·5	1257

AUSTIN TO MASON CITY.

This agrees with connecting railways at Lyle, Plymouth Junction, and Mason City.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Austin Junction, with main line of the Iowa and Minnesota division	104·1	1200
Rose Creek, water, 1,171; grade	107·5	1191
Summit, grade	109·0	1213
Depression, grade	113·7	1191
Lyle	115·0	1206
Same, junction with Minnesota Branch of the Illinois Central Railroad, and crossing the Chicago, St. Paul and Kansas City Railway	115·2	1200
At the State line, grade	115·4	1192
Red Cedar River, water, 1,124; grade	118·2	1147
Otranto	118·8	1170
Carpenter	122·2	1190
Grafton	128·7	1223
Plymouth	135·2	1175
Plymouth Junction, Burlington, Cedar Rapids and Northern Railway	136·1	1125
Junction with the Central Iowa Railway	143·1	1125
Junction with the Iowa and Dakota division	143·2	1127
Mason City, 116 miles from North McGregor	143·4	1128

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

DECORAH BRANCH.

This agrees with the Burlington, Cedar Rapids and Northern Railway at Decorah.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Conover, junction with the main line of the Iowa and Minnesota divison	169·5	1235
Creek, top of bank, 1,058; water	172·3	1052
Creek, top of bank, 994; water	175·0	984
Creek, top of bank, 897; water	178·0	885
Decorah	178·5	875

SOUTHERN MINNESOTA DIVISION, MAIN LINE, LA CROSSE TO WOONSOCKET.

This division and the Mankato Branch are from manuscripts and profiles furnished by George B. Woodworth, assistant engineer, Milwaukee.

Notes of this division, which were received in 1881, extending from La Crosse to 5 miles west of the James River, and including the Mankato Branch and the line to Sioux Falls, give elevations above low water of the Mississippi River at La Crosse, where they are referred to sea level by the determination of that elevation by United States engineers. Comparing these notes with the connecting railways, which latter are known to be correct by their mutual agreements, they are found to match exactly at Ramsey, Albert Lea, Winnebago City, and the Blue Earth River, and on the Mankato Branch; but in proceeding thence westward additions are required and are here made as follows: At Prairie Junction, 7 feet; and at Sioux Falls Junction and forward across the James River, 10 feet, making a discrepancy of 3 feet with the preceding. These additions begin at the stations mentioned, and that at Prairie Junction continues to the next correction. Four feet of the discrepancy between the Blue Earth River and Prairie Junction are allowed at the east end and 3 feet at the west end of the intervening portion. With these adjustments, the greater part of the series is known to be correct, and the limits of error in other parts nowhere exceed 4 feet.

	From LaCrosse	Above the sea.
	Miles.	*Feet.*
La Crosse Bridge, extreme low water of the Mississippi River, 628·0; extreme high water (1880), 643·5	2·8	628–643·5
Junction with the River division, near west end of bridge	3·2	655
La Crescent	4·1	649
Junction with the Dubuque division	6 4	643
Root River bridge	7·6	650
Hokah	9·9	651
Root River bridge	15·0	665
Mound Prairie	16·2	662
Root River bridge	18·0	671
Houston	23·1	681
Root River bridge	26·6	705
Money Creek Station	27·5	701
Rushford	34·8	724
Peterson	39·8	758
Whalan	49·1	788
Root River bridge	52·0	803
Root River bridge	53·5	826
Lanesboro	54·0	843
Root River bridge	57·7	875
Isinour's	59·6	901
Fountain	65·3	1304
Depression, grade	66·6	1261
Summit, grade	70·7	1332
Wykoff	72·4	1312
Summit, grade	74·5	1369
Spring Valley	79·6	1268

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

SOUTHERN MINNESOTA DIVISION—Continued.

	From La Crosse.	Above the sea.
	Miles.	*Feet.*
Summit, grade	86·1	1360
Grand Meadow	89·0	1 40
Depression, grade	91·2	1319
Dexter	95·7	1416
Brownsdale	104·0	1275
Red Cedar River, water	108·9	1199
Ramsey, crossing the Iowa and Minnesota division	109·1	1221
Turtle Creek, water, 1,192; grade	113·7	1205
Oakland	115·9	1273
Summit, grade	119·8	1278
Depression, grade	123·6	1249
Hayward	124·0	1256
Summit, grade	127·5	1271
Depression, grade	130·2	1214
Albert Lea	130·6	1229
Crossing the Burlington, Cedar Rapids and Northern and Minneapolis and St. Louis Railways	130·7	1228
Summit, grade	134·9	1331
Armstrong	135·8	1278
Summit, grade	139·5	1325
Alden	141·2	1269
Evans	145·8	1197
Wells	150·3	1161
Junction of the Mankato Branch	150·6	1153
Easton	159·3	1054
Summit, grade	163·1	1085
Delavan	165·3	1065
Depression, grade	165·6	1055
Crossing the Blue Earth Branch of the Chicago, St. Paul, Minneapolis and Omaha Railway	172·2	1103
Winnebago City	172·4	1104
Blue Earth River, water	174·5	1022
Fairmont	189·4	1188
Sherburne	202·1	1285
Top of bluff at junction of branch to Jackson depot	214·5	1458
Des Moines River, water, 1,300; grade	217·2	1365
Summit, grade	222·9	1529
Lakefield	226·9	1475
Okabena	235·3	1422
Prairie Junction, crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	238·4	1429
Kinbrae (De Forest)	245·7	1461
Graham Lakes, water	245·7	1448
Fulda	252·2	1523
Iona	262·2	1623
Summit, grade	266·0	1720
Entering the Chanarambie Valley, grade	270·6	1649
Chanarambie Creek, water at last crossing	279·7	1536
Edgerton	281·2	1565
Rock River, water	284·2	1567
Hatfield	288·2	1677
Summit, highest on this division, grade	290·7	1759
Pipestone	295·3	1708
Pipestone Creek, water	299·0	1592
Airlie	301·4	1644
Flandreau	310·1	1565
Big Sioux River, water	312·6	1510
Egan	314·5	1525
Sioux Falls Junction, Sioux City and Dakota division	316·4	1514
Summit, grade	321·5	1713
Summit, grade	335·0	1723
Summit, grade	337·3	1709

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continue

SOUTHERN MINNESOTA DIVISION—Continued.

	From La Crosse.	Above th
	Miles.	*Feet.*
Madison Lake, 2 miles south of last, water	337·3	
Madison, junction of line to Bristol	339·6	
Lake Herman, water, 1664; grade	342·0	
Summit of morainic hills, approximately	348·8	
Top of river bluff	349·0	
East Vermilion River near Winfred, water	350·9	
Top of river bluff	352·3	
Top of river bluff	359·1	
West Vermilion River, water	360·8	
Howard	361·3	
Bone Creek, bed, 1,477; grade	363·8	
Top of creek bluff	367·4	
Rock (or Red Stone) Creek, bed, 1,382; water, 1,385; grade	367·7	
Top of creek bank	368·3	
Little Jim Flats	377·4	
Artesian	380·9	
Top of river bluff	388·1	
James River, about 160 feet wide, water, 1,213; grade	389·6	
Forestburg	390·4	
Prairie 5 miles west of James River	394·6	
Woonsocket, junction with the James River division	399·4	

MANKATO BRANCH.

Agreeing at Mankato with the Chicago, St. Paul, Minneapolis and Omaha Rail and with the survey of the Minnesota River by United States engineers.

	From LaCrosse.	Above the
	Miles	*Feet.*
Junction with the Southern Minnesota division, main line, near Wells	150·6	
Minnesota Lake Station	158·8	
Mapleton	167·4	
Maple River, water	174·5	
Good Thunder	175·2	
Rapidan	181·5	
Le Sueur River, water, 780; grade	183·9	
Junction, crossing the Chicago, St. Paul, Minneapolis and Omaha Railway	187·3	
Mankato	188·4	
Minnesota River, ordinary stage of low water, 756; extreme low and high water	188·4	75

OWA AND DAKOTA DIVISION, MAIN LINE, NORTH McGREGOR TO CHAMBERL

This division (with its Estherville, Okoboji, and Running Water branches), ex ing the portion of the main line between North McGregor and Algona, is from Ge B. Woodworth, assistant engineer, Milwaukee.

Referred to sea level by the elevation of the Mississippi River at North McGr determined by United States engineers, and agreeing exactly or closely with necting railways and other branches of this system at Calmar, Mason City, Gar Britt, Emmetsburg, Sheldon, Canton Junction, Parker, Marion Junction, and M ell, and with the elevation of the Missouri River at Chamberlain, determine the Missouri River Commission.

Between Calmar and Mason City this accordance is furnished by the profiles o Iowa and Minnesota Division from Calmar to Austin and of the Austin and M City line; but on the profile of this main line a discrepancy of 10 feet exists in

distance, by which Mason City would be placed too low. Approximate comparisons with intersecting railways at New Hampton and Nora Junction indicate that this discrepancy probably lies between these stations; and therefore half of it is allowed at each end of the intervening portion.

A further discrepancy of 5 feet exists between Mason City and Britt, which would lower the crossing of the Minneapolis and St. Louis Railway at Britt and the line thence westward. Three feet of this is allowed at the east end of the intervening portion, and 2 feet at its west end.

From North McGregor to Calmar, and from Britt to Chamberlain, the profile has received no adjustments. An exact comparison is supplied by the Sioux City and Dakota division at Sioux Falls, where it is in agreement with the Chicago, St. Paul, Minneapolis and Omaha and the Burlington, Cedar Rapids and Northern Railways. Together with its connections through the Sioux City and Dakota division, it gives elevations of the Missouri River, stated to be low water, at Sioux City and Chamberlain, which are respectively about 5 and 7 feet above the elevations of extreme low water determined by the Missouri River Commission. It is probable, however, that these are harmonious, the reference of the railway profiles being not to extreme low water, but to the average low stage of the river as it is maintained through the greater part of the year; for a comparison with the Missouri River at Yankton is supplied by Mr. E. D. Palmer, city engineer, showing that this railway there agrees with the leveling of the Missouri River Commission, or possibly falls 1 or 2 feet lower.

	From North McGregor.	Above the sea.
	Miles.	*Feet.*
Mississippi River at North McGregor, extreme low and high water	0·0	604–626
North McGregor	0·0	625
(Grade at 4·1 miles, 753; at 7·6 miles, near Beulah, 8·9; and at 11·2 miles, 1,053 feet.)		
Monona	14·1	1209
Summit, cutting 3 feet; grade	14·2	1213
Luana	17·9	1120
Depression, filling 6 feet; grade	18·3	1106
Summit, cutting 5 feet; grade	20·8	1197
Line of Clayton and Allamakee Counties, grade	22·6	1182
Creek, bed, 1,132; grade	23·3	1149
Postville	24·5	1195
Summit, cutting 5 feet; grade	25·2	1214
Line of Allamakee and Winneshiek Counties, grade	26·6	1205
Castalia	30·6	1245
Ossian	35·7	1269
Creek, bed, 1,224; grade	41·1	1246
Calmar, junction with the Iowa and Minnesota division, 172·5 miles from Minneapolis	42·0	1257
Turkey River, water, 990; grade	47·3	1006
Fort Atkinson	47·7	1011
Summit, cutting 7 feet; grade	52·5	1174
Little Turkey River, water, 1,047; grade	55·2	1064
Summit, cutting 16 feet; grade	57·8	1148
Crane Creek, water, 1,061; grade	59·6	1073
Summit, cutting 22 feet; grade	62·0	1178
Summit, cutting 15 feet; grade	62·9	1196
Plum Creek, water, 1,106; grade	64·8	1118
East Wapsipinicon River, water, 1,098; grade	66·5	1110
New Hampton, near crossing of the Chicago, St. Paul and Kansas City Railway	69·0	1154
Middle Wapsipinicon River, water, 1,054; grade	72·8	1070
Chickasaw (a summit of grade)	76·6	1141
Beaver Brook, water, 995; grade	80·8	1008
Little Cedar River, water, 1,001; grade	82·5	1013
Summit, cutting 5 feet; grade	85·4	1126
Crossing the Minnesota Branch of the Illinois Central Railroad	88·1	1013
Charles City	88·5	1005
Red Cedar River, water, 988; grade	89·6	1001
Summit, natural surface and grade	93·5	1080
Summit, natural surface and grade	98·9	1125

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continue

IOWA AND DAKOTA DIVISION—Continued.

	From North McGregor.	Above the
	Miles.	*Feet.*
Flood Creek, water, 1,076; grade	101·5	
Summit, cutting 3 feet; grade	104·0	
Shell Rock River near Nora Junction, Burlington, Cedar Rapids and Northern Railway, water, 1,031; grade	106·4	
Summit, cutting 8 feet; grade	109·0	
Lime Creek, water, 1,050; grade	112·5	
Crossing the Central Iowa Railway, Mason City	115·65	
Junction with the Austin and Mason City Line, Iowa and Minnesota division	115·8	
Mason City, 143·4 miles from Minneapolis	116·0	
Summit, natural surface and grade	119·1	
Crane Creek, water, 1,158; grade	120·4	
Willow Creek, water, 1,164; grade	121·0	
Same, water, 1,176; grade	122·4	
Clear Lake Station	125·6	
Summit, cutting 4 feet; grade	131·5	
Garner, crossing branch of the Burlington, Cedar Rapids and Northern Railway	137·0	
East Fork of Iowa River, water, 1,201; grade	137·9	
West Fork of Iowa River, water, 1,204; grade	144·3	
Crossing the Minneapolis and St. Louis Railway	146·1	
Britt	147·1	
Summit, cutting 3 feet; grade	155·1	
Wesley	156·8	
Algona	168·2	
East Fork of Des Moines River, water, 1,105; grade	169·9	
Whittemore	179·4	
Emmetsburg, junction of the Estherville Branch	192·4	
Des Moines River, here, about	192·4	
Ruthven	203·7	
Spencer, junction of the Okoboji Branch	216·5	
Hartley	233·3	
Sanborn	242·4	
Sheldon, near crossing of the Chicago, St. Paul, Minneapolis and Omaha Railway	252·7	
Boyden	259·8	
Hull	266·5	
Summit, grade	268·2	
Rock Valley	275·1	
Rock River, water, 1,226; grade	275·2	
Inwood (a summit of grade)	285·1	
Big Sioux River, bed, 1,225; water, 1,228; grade	291·6	
Canton	294·6	
Canton Junction, crossing the Sioux City and Dakota division	295·2	
Worthing	303·8	
Lennox	310·6	
Depression, Saddle Creek, natural surface, 1,324; grade	311·8	
Summit, natural surface and grade	314·2	
Vermilion River, bed, 1,286; grade	319·3	
Parker, near crossing of the Chicago and Northwestern Railway	323·2	
West Fork of Vermilion River, bed, 1,326; water, 1,328; grade	324·9	
Summit, natural surface and grade	328·2	
Marion Junction, Running Water Branch	329·7	
Creek, bed, 1,400; grade	333·2	
Summit, natural surface and grade	338·8	
Bridgewater	344·8	
Pierre Creek, bed, 1,281; grade	359·6	
Alexandria	360·6	

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

IOWA AND DAKOTA DIVISION—Continued.

	From North McGregor.	Above the sea.
	Miles.	*Feet.*
Johnson's Creek, bed, 1,263; grade	365·1	1292
Summit, cutting 6 feet; grade	367·3	1341
James River, bed, 1,203; water, 1,206; grade	370·7	1220
Mitchell	374·0	1301
Junction with the James River division	374·7	1297
Mount Vernon	385·8	1413
Plankinton	397 6	1528
White Lake Station	409·1	1646
Kimball	421·3	1788
Puckwana	431·8	1546
Chamberlain	441·0	1363
Missouri River here, low water	441·0	1330
(Probably this refers to the average low stage of the river through the greater part of the year. Low water November 30, 1882, was 1,324·30, according to leveling and gauge records of the Missouri River Commission; but the extreme low water of 1873 was 1 foot lower—about 1,323 feet.)		

ESTHERVILLE BRANCH.

This agrees with the Burlington, Cedar Rapids and Northern Railway.

	From North McGregor.	Above the sea.
	Miles.	*Feet.*
Emmetsburg, junction with the Iowa and Dakota division, main line	192·4	1237
Crossing the Burlington, Cedar Rapids and Northern Railway	198·4	1233
High Lake Station	206·6	1266
Des Moines River, water, 1,236; grade	207·4	1254
Same, water, 1,250; grade	213·9	1280
Estherville	214·8	1298

OKOBOJI BRANCH.

Comparison with the Burlington, Cedar Rapids and Northern Railway profile, by which the elevation of Spirit Lake is determined at 1,395 feet, indicates for this branch a subtraction of 10 feet at East Okoboji Lake, which is about 5 feet below Spirit Lake. Excepting the junction at Spencer, this subtraction is made at all the points here noted.

	From North McGregor.	Above the sea.
	Miles.	*Feet.*
Spencer, junction with the Iowa and Dakota division, main line	216·5	1319
Summit, grade	224·0	1439
Outlet of Spirit and Okoboji Lakes, water, 1,365; grade	228·5	1396
East Okoboji Lake, water, 1,390; grade	233·5	1397
Spirit Lake Station	237·2	1458

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued

RUNNING WATER BRANCH.

This agrees with the elevations of the Missouri River at Yankton and Runni Water, determined by the Missouri River Commission.

	From North McGregor.	Above the s
	Miles.	*Feet.*
Marion Junction, Iowa and Dakota division, main line ..	329·7	1
Freeman	340·1	1
Menno	351·0	1
James River, water, 1,178; grade	355·3	1
James River Station	355·7	1
Scotland	360·8	1
Junction of Yankton and Scotland line	361·8	1
Tyndall	373·8	1
Springfield	385·5	1
Running Water	392·1	1
(Missouri River here, low water November 18–30, 1881, 1,203·50 (Missouri River Commission); extreme low water, about 1,201·50 feet. The railway profile agrees with this, at least approximately; but it fails to note the elevation of the river, so that no exact comparison is supplied.)		

SIOUX CITY AND DAKOTA DIVISION, MAIN LINE, SIOUX CITY TO EGAN.

This line and its branch to Yankton and Scotland are from George B. Woodwo assistant engineer, Milwaukee.

It agrees with connecting railways and other divisions and branches of this syst at Elk Point, Hawarden, Canton Junction, and Sioux Falls, and with leveling the Missouri River Commission at Sioux City.

	From Sioux City.	Above the s
	Miles.	*Feet.*
Sioux City	0·0	1
Missouri River here, low water	0·0	1
(Probably this refers, as at Chamberlain, on the Iowa and Dakota division, to the average low stage of the river. Its extreme low and high water at Sioux City, determined by the Missouri River Commission, are 1,076·5–1,099 feet.)		
On river bluff, heavy side-cutting	1·5	1
Big Sioux River, water, 1,088; grade	2·6	1
McCook	7·7	1
Jefferson	12·5	1
Elk Point, junction of the Yankton and Scotland line	21·0	1
Big Sioux River, water, 1,098; grade	24·5	1
Westfield	27·7	1
Akron	33·2	1
Crossing the Chicago and Northwestern Railway, Hawarden	45·2	1
Calliope	46·2	1
Big Sioux River, water, 1,162; grade	49·0	1
Eden	55·0	1
Big Sioux River, water, 1,169; grade	56·0	1
Austin	57·8	1
Big Sioux River, water, 1,181; grade	58·0	1
Fairview	61·7	1
Big Sioux River, water, 1,186; grade	62·0	1
Beloit	68·2	1

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

SIOUX CITY AND DAKOTA DIVISION.—Continued.

	From Sioux City.	Above the sea.
	Miles.	*Feet.*
Big Sioux River, water, 1,224; grade	68·4	1239
Canton Junction, crossing the Iowa and Dakota division	70·2	1263
Harrisburg	82·8	1419
Summit, grade	85·0	1502
Crossing the Burlington, Cedar Rapids and Northern Railway	88·0	1406
Big Sioux River, low and high water, 1,373–1,378; grade	90·5	1395
(This is close below the upper dam of Sioux Falls, that of the Cascade Mills, owned by Emerson, Sherman & Co., which has a head of 10 feet, from 1,383 to 1,373 feet. Canal of the Queen Bee Mills, owned by the Sioux Falls Water Power Company, 1,373; tail-race of same, 1,317; the head or fall used being 56 feet. Pond of the lowest dam, that of the Sioux Falls Mills, owned by Webber, Shaw & Martin, 1,317. This has 10 feet head. Low water in the river below it, 1,307 feet above the sea, is taken as zero of the Sioux Falls city system of levelings.)		
Sioux Falls	90·6	1393
D. C. Rice, city engineer, supplies the following elevations of track at depots in Sioux Falls:		
Chicago, Milwaukee and St. Paul	.....	1393
Chicago, St. Paul, Minneapolis and Omaha	.....	1397
Illinois Central	.....	1397
Burlington, Cedar Rapids and Northern	.....	1400
Top of steeply ascending grade from Sioux Falls	91·7	1422
Big Sioux River, water	109·2	1470
Dell Rapids	109·5	1485
Big Sioux River, water	116·4	1479
Big Sioux River, water	121·5	1497
Sioux Falls Junction, Southern Minnesota division	122·3	1514
Egan	124·2	1525

ELK POINT TO YANKTON, SCOTLAND, ARMOUR, AND MITCHELL.

Agreeing at Yankton with the Chicago and Northwestern Railway and with leveling by the Missouri River Commission, at Scotland with the Running Water Branch, and at Mitchell with the Iowa and Dakota division.

	From Sioux City.	Above the sea.
	Miles.	*Feet.*
Elk Point, junction with the foregoing	21·0	1131
Burbank	29·6	1142
Vermilion	35·5	1150
Vermilion River, water, 1,129; grade	37·0	1150
Meckling	43·8	1156
Gayville	50·0	1167
James River, water, 1,161; grade	57·0	1177
Junction of the spur to Yankton	60·0	1180
Yankton (on spur, 1·4 miles from main line)	61·4	1196
Missouri River here, low water November 24, 1881, 1,160·76; extreme low and high water, about	61·4	1157–1198
Summit, grade	65·3	1358
Utica	69·0	1387

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

ELK POINT TO YANKTON, ETC.—Continued.

	From Sioux City.	Above the sea.
	Miles.	*Feet.*
Depression, grade	73·0	1299
Lesterville	77·0	1385
Junction with the Running Water Branch	87·1	1364
Scotland	88·1	1347
Tripp	101·6	1563
On branch from Tripp west to Armour:		
Summit, grade	104·1	1595
Delmont	111·6	1488
Armour	121·6	1521
On line from Tripp north to Mitchell:		
Parkston	113·7	1400
Ethan	124·2	1345
Mitchell, junction with the Iowa and Dakota and James River divisions	135·8	1301

MADISON TO BRISTOL, AND ANDOVER TO HARLEM.

Agreeing with the Southern Minnesota and Hastings and Dakota divisions, and with other intersecting railways.

	From Madison.	Above the sea.
	Miles.	*Feet.*
Madison, on the Southern Minnesota division, 339·6 miles from La Crosse	0·0	1669
Ramona (a summit of grade)	10·3	1801
Oldham	19·9	1721
Lake Whitewood, water, 1,687; grade on bridge	26·6	1694
Lake Preston Station	30·3	1722
Crossing the Chicago and Northwestern Railway	30·5	1724
Erwin (a summit of grade)	40·0	1860
Bryant	47·5	1844
Kent, crossing the Watertown and Huron Branch of the St. Paul, Minneapolis and Manitoba Railway	54·1	1829
Naples	60·6	1791
Crossing the Chicago and Northwestern Railway	68·9	1814
East Elrod	69·4	1818
Garden City	74·3	1853
Summit, grade	75·8	1862
Bradley	84·4	1796
Summit, grade	89·9	1862
Butler	96·7	1820
Bristol, Hastings and Dakota division, 247·6 miles from Minneapolis	103·2	1775
Andover, Hastings and Dakota division, junction of branch to Harlem	113·2	1476
Pierpont (a summit of grade)	120·5	1512
Langford	128·1	1372
Spain	135·3	1327
Britton	141·6	1354
Newark	151·6	1308
Brampton	156·1	1291
Sargent	161·8	1303
Crossing the Minneapolis and Pacific Railway	163·8	1298
Harlem	168·8	1323

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

JAMES RIVER DIVISION, MITCHELL TO ELLENDALE AND EDGELEY.

This agrees exactly or closely with connecting railways and other branches of this system at Woonsocket, Wolsey, Redfield, Aberdeen, Ellendale, and Edgeley.

	From Mitchell.	Above the sea.
	Miles.	*Feet.*
Mitchell, 374 miles from North McGregor	0·0	1301
Junction with the Iowa and Dakota division	0·7	1297
Letcher	15·0	1300
Depression (Long Lake) filling 6 feet; grade	19·2	1289
Summit, natural surface and grade	22·5	1315
Woonsocket, junction with the Southern Minnesota division	28·2	1308
Sand Creek, bed, 1,310; top of creek bank, 1,316; grade	35·8	1319
Alpena	38·0	1319
Summit, natural surface and grade	42·8	1363
Virgil	46·4	1341
Depression, filling 6 feet; grade	48·7	1316
Wolsey	54·6	1353
Crossing the main line of the Dakota division of the Chicago and Northwestern Railway	55·0	1352
Cain Creek, bed, 1,320; grade	57·1	1329
Summit, cutting 4 feet; grade	59·2	1360
Bonilla	67·0	1338
Tulare	77·7	1317
Depression, filling 7 feet; grade	80·0	1297
Summit, natural surface and grade	81·9	1331
Crossing the Columbia Branch of the Chicago and Northwestern Railway	85·7	1296
Redfield	87·2	1295
Crossing the Watertown line of the Chicago and Northwestern Railway	87·4	1294
Turtle Creek, bed, 1,254; top of creek bank, 1,274; grade	87·8	1278
Snake Creek, bed, 1,248; top of creek bank, 1,270; grade	93·3	1270
Ashton	95·7	1296
Ravine, bottom, 1,283; grade	100·3	1300
Mellette	106·7	1300
Ravine, bottom, 1,276; grade	116·6	1290
Warner	118·4	1301
Ravine, bottom, 1,281; grade	122·3	1291
Crossing the Columbia Branch of the Chicago and Northwestern Railway	125·5	1299
Aberdeen, junction with the Hastings and Dakota division	128·3	1300
Summit, grade	139·3	1361
Westport	141·1	1333
Elm River, bed, 1,318; top of river bank, 1,330; grade	141·3	1333
Summit, natural surface and grade	150·6	1401
Frederick	153·9	1371
Maple River, bed, 1,359; grade	154·4	1371
Summit, natural surface and grade	161·1	1440
Depression, filling 12 feet; grade	161·6	1419
Ellendale, near crossing of the St. Paul, Minneapolis and Manitoba Railway	165·7	1449
Duane	170·6	1478
Monango, near crossing of the Minneapolis and Pacific Railway	178·1	1503
Summit, grade	191·4	1566
Edgeley, near crossing of branch of the Northern Pacific Railroad	192·2	1556

CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY SYSTEM—Continued.

ORIENT TO EUREKA.

Referred to sea level by the line from Aberdeen, and agreeing (at least approximately) with the Chicago and Northwestern Railway.

	From Orient.	Above the sea.
	Miles.	*Feet.*
Orient	0·0	1599
Faulkton, near crossing of the Chicago and Northwestern Railway	9·3	1573
Millard	18·3	1640
Loyalton	29·0	1685
Roscoe, 328 miles from Minneapolis, on line from Aberdeen to Bowdle	41·3	1826
Hosmer	52·4	1901
Hillsview	59·6	1849
Eureka	67·6	1884

CHICAGO AND NORTHWESTERN RAILWAY.

[From John E. Blunt, engineer, Winona.]

MINNESOTA (WINONA AND ST. PETER) DIVISION, AND ITS EXTENSION IN SOUTH DAKOTA, MAIN LINE, FROM WINONA TO ST. PETER, TRACY, WATERTOWN, REDFIELD, AND GETTYSBURG.

Referred to sea level by the elevation of the Mississippi River at Winona, determined by United States engineers, and agreeing exactly or closely with connecting railways and other divisions and branches of this system at Winona, Zumbrota Junction, Dodge Centre, Owatonna, Waseca, Kasota, Redwood Junction, Tracy, Watertown, Doland, and Redfield.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Winona, extreme low and high water of the Mississippi River	0·0	639·19–656·27
Top of rail on drawbridge	0·0	670
Winona, passenger depot	0·0	668
Winona, railroad yard and freight depot	0·0	649
Minnesota City	5·9	676
Stockton	11·3	753
Lewiston	18·3	1211
Utica	22·7	1170
St. Charles	28·3	1139
Dover	32·2	1138
Eyota	36·9	1237
Chatfield Junction	37·7	1275
Plainview Junction	37·9	1275
Chester	42·7	1122
Rochester	49·2	991
Zumbrota Junction	50·6	999
Olmsted	54·2	1054
Byron	58·7	1250
Kasson	63·9	1252
Dodge Centre, near crossing of the Chicago, St. Paul and Kansas City Railway	69·2	1288
Claremont	76·3	1280
Havana	83·9	1246
Owatonna, near crossing of the Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul Railway	88·2	1144
Meriden	96·3	1149
Waseca, near crossing of the Minneapolis and St. Louis Railway	102·6	1153
Janesville	112·9	1063
Eagle Lake Station	122·5	1012
Mankato Junction	128·0	906

CHICAGO AND NORTHWESTERN RAILWAY—Continued.

MINNESOTA DIVISION, ETC.—Continued.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Mankato (on spur, 3 miles from main line)	131·0	781
Kasota, junction with Chicago, St. Paul, Minneapolis and Omaha Railway	133·8	804
Minnesota River, low and high water, 733–755; grade	135·0	791
St. Peter	136·2	812
Oshawa	146·3	982
Nicollet	150·9	980
Courtland	158·5	936
Minnesota River, low and high water, 782–807; grade	162·5	821
New Ulm	165·3	837
Milford	169·0	994
Sleepy Eye	179·7	1034
Redwood Junction, Redwood Falls Branch	180·7	1015
Springfield	193·2	1025
Sanborn	201·5	1089
Lamberton	208·8	1144
Walnut Grove	219·0	1223
Tracy, junction of the Dakota division	226·5	1403
Amiret	233·6	1283
Marshall, near crossing of the Willmar and Sioux Falls (St. Paul, Minneapolis and Manitoba) Railway	243·8	1174
Grand View	250·7	1173
Minneota	256·5	1179
Canby	274·0	1243
Gary	284·6	1484
Altamont	297·4	1834
Goodwin (crest of the Coteau des Prairies)	305·9	1996
Kranzburg	309·5	1982
Watertown, junction with line from Brookings	319·1	1733
(According to Mr. George W. Carpenter, county surveyor, Watertown, this depot is 1 foot below that of the Minneapolis and St. Louis and Burlington, Cedar Rapids and Northern Railways, and 7 feet above that of the St. Paul, Minneapolis and Manitoba Railway.)		
Crossing the St. Paul, Minneapolis and Manitoba Railway	319·8	1726
Big Sioux River, low and high water	320·0	1709–1715
Lake Kampeska, water	322·0	1714
Kampeska	327·3	1766
Henry	337·0	1812
Elrod, near crossing of the Chicago, Milwaukee and St. Paul Railway	342·3	1807
Clark Centre	350·2	1789
Summit, grade	351·5	1854
Raymond	361·4	1458
Doland, junction of the Groton Branch	369·4	1355
Frankfort	379·4	1296
James River, water	380·8	1240
Redfield, junction with line from Huron to Oakes	390·2	1300
Zell	400·8	1365
Rockham	405·4	1394
Miranda	413·8	1447
Crossing the Chicago, Milwaukee and St. Paul Railway	422·3	1582
Faulkton	422·7	1595
Snake Creek, low water	424·0	1558
Burkmere	432·2	1748
Seneca	442·0	1911
Summit, grade	451·8	2045
Lebanon (in the Blue Blanket Valley)	455·1	1956
Summit, grade	464·0	2104
Gettysburg	465·5	2082

CHICAGO AND NORTHWESTERN RAILWAY—Continued.

CHATFIELD BRANCH.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Chatfield Junction, Minnesota division, main line	37·7	1275
Summit, grade	40·7	1295
Chatfield	48·9	976

PLAINVIEW BRANCH.

Plainview Junction, Minnesota division, main line	37·9	1275
Doty	40·0	1310
Viola	43·0	1129
Whitewater Creek, grade	47·0	1055
Elgin	48·2	1069
Plainview	52·9	1167

ZUMBROTA BRANCH.

Agreeing at Zumbrota with the Wabasha division of the Chicago, Milwaukee and St. Paul Railway.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Zumbrota Junction, Minnesota division, main line	50·6	999
Douglas	58·2	1091
South Middle Branch of Zumbro River, water, 966; grade	60·2	986
Oronoco	61·7	1041
North Middle Branch of Zumbro River, water, 984; grade	65·2	993
Pine Island	65·8	998
Lena	70·6	1073
Forest Mills	73·1	1023
Zumbrota	74·5	971

REDWOOD FALLS BRANCH.

Agreeing at Redwood Falls with leveling from the Minneapolis and St. Louis Railway.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Redwood Junction, Minnesota division, main line	180·7	1015
Morgan	193·2	1050
Paxton	199·4	1039
Redwood Falls	205·7	1033
Redwood River here, at the head of the falls	205·7	953
Same, at the Minneapolis and St. Louis Railway bridge, below the falls, 2¼ miles northeast from the last	.....	831

CHICAGO AND NORTHWESTERN RAILWAY—Continued.

GROTON BRANCH.

Agreeing at Groton with the Hastings and Dakota division of the Chicago, Milwaukee and St. Paul Railway.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Doland, junction with extension of the Minnesota division, main line	369·4	1355
Turton	380·3	1323
Conde	387·8	1313
Verdon	393·8	1304
Ferney	399·6	1300
Groton, junction with the Chicago, Milwaukee and St. Paul Railway	408·2	1301

DAKOTA DIVISION, MAIN LINE, TRACY TO PIERRE.

This agrees exactly or closely with connecting railways and other branches of this system at Elkton, Watertown Junction, Iroquois, James Valley Junction, and Wolsey. At Pierre the elevation of the Missouri River is found about 13 feet higher by this survey than by the leveling of the Missouri River Commission.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Tracy, junction with the Minnesota (Winona and St. Peter) division	226·5	1403
Balaton	239·5	1528
Redwood	246·5	1631
Redwood River, water, 1,592; grade	246·6	1631
Tyler	253·7	1750
Lake Benton Station	261·5	1759
Lake Benton, water	261·5	1754
Summit (Hole in the Mountain), grade	262·5	1762
Depression, grade	265·5	1715
Verdi	267·6	1771
Elkton, near crossing of the Burlington, Cedar Rapids and Northern Railway	274·3	1751
Aurora	285·1	1630
Summit, grade	288·9	1683
Brookings	290·8	1636
Watertown Junction	294·3	1604
Big Sioux River, water, 1,596; grade	296·4	1607
Volga	297·4	1636
Arlington (Nordland)	308·3	1846
Preston	321·0	1696
De Smet	329·6	1726
Summit, grade	331·4	1767
Manchester (Fairview)	338·3	1542
Iroquois, junction of the Hawarden line	344·8	1401
Cavour	354·0	1311
James River, water, 1,228; grade	361·8	1270
Huron	362·9	1285
James Valley Junction, line to Redfield and Oakes	367·0	1312
Wolsey, near crossing of the James River division, Chicago, Milwaukee and St. Paul Railway	375·6	1348
Wessington	387·6	1419
St. Lawrence	400·3	1580
Miller	402·8	1587
Ree Heights	413·3	1731
Brandhall	419·4	1815
Highmore	425·2	1890
Summit, grade	427·4	1903
Holabird	433·0	1795

CHICAGO AND NORTHWESTERN RAILWAY—Continued.

DAKOTA DIVISION—Continued.

	From Winona.	Above the sea.
	Miles.	*Feet.*
Harold	439·7	1801
Medicine Creek, water	448·0	1652
Blunt	452·3	1621
Canning	461·8	1553
Medicine Creek, water	467·6	1408
Rousseau	467·8	1427
East Pierre	480·7	1460
Pierre	482·0	1440
Missouri River here, low water (1879), 1,428; extreme low water (1882), about 1,426; ordinary stage of high water, 1,440; extreme high water (1881), 1,445 (According to leveling by the Missouri River Commission, low water at Pierre November 30, 1882, was 1,413·80, extreme low water being about 1,413 feet.)	482·0	1426–1445

BROOKINGS TO WATERTOWN.

Agreeing with connecting railways at Watertown.

	From Brookings.	Above the sea.
	Miles.	*Feet.*
Watertown Junction, Dakota division, main line, 294·3 miles from Winona	3·5	1604
Bruce	11·7	1640
Estelline	21·8	1659
Dempster	26·5	1666
Castlewood	34·0	1685
Appleby	40·6	1711
Watertown, junction with the Minnesota division	47·8	1733

HURON TO REDFIELD AND OAKES.

Agreeing with connecting lines at Redfield and Aberdeen; but farther north requiring a subtraction of 8 feet, which is here made, beginning at Ordway, to agree with railways at Ludden and Oakes. With this change it accords well with the known elevations of the James River, which is held level by the Columbia dam along a distance of about 30 miles to Ludden.

	From Huron.	Above the sea.
	Miles.	*Feet.*
James Valley Junction, Dakota division, main line, 367 miles from Winona	4·1	1312
Broadland	12·4	1308
Hitchcock	22·2	1339
Crandon	32·6	1305
Redfield, crossing the extension of the Minnesota division	40·4	1300
Athol	50·4	1296
Northville	60·6	1299
Mansfield	66·6	1300
Rudolph	74·0	1301
Aberdeen, junction with the Chicago, Milwaukee and St. Paul and the St. Paul, Minneapolis and Manitoba Railways	82·6	1300
Maple River, low water	91·0	1299
Ordway	91·1	1306
James River, below the Columbia Mills (head, 10 feet)	96·0	1276

CHICAGO AND NORTHWESTERN RAILWAY—Continued.

HURON TO REDFIELD AND OAKES—Continued.

	From Huron.	Above the sea.
	Miles.	*Feet.*
Lake Columbia, James River (raised by dam 8 feet above its natural level), 1,286; grade on bridge	96·5	1295
Columbia	96·8	1304
Houghton	108·5	1302
Hecla	117·2	1301
Ludden	126·1	1303
James River, low water (level of Lake Columbia), 1 mile west of Ludden	.....	1286
Crossing the St. Paul, Minneapolis and Manitoba Railway	127·6	1303
Crossing the Minneapolis and Pacific Railway	135·6	1321
Oakes, connection with the Northern Pacific Railroad.... (James River, low water, 4 miles below La Moure, 1,287 feet.)	136·1	1313

HAWARDEN TO IROQUOIS.

This agrees with its connecting railways.

	From Hawarden.	Above the sea.
	Miles.	*Feet.*
Hawarden, near the crossing of the Sioux City and Dakota division of the Chicago, Milwaukee and St. Paul Railway	0·0	1181
Big Sioux River, water	1·0	1147
Alcester	8·6	1346
Beresford	17·4	1505
Centerville, junction of the Yankton Branch	27·6	1229
Hurley	40·7	1268
Parker, near crossing of the Iowa and Dakota division of the Chicago, Milwaukee and St. Paul Railway	49·6	1340
Canistota	65·9	1455
Salem, near junction with the Sioux Falls Branch of the Chicago, St. Paul, Minneapolis and Omaha Railway	76·0	1517
Canova	88·1	1527
Vilas	98·2	1480
Carthage	110·7	1438
Esmond	117·6	1433
Iroquois, junction with the Dakota division, main line	126·2	1401

YANKTON BRANCH.

This agrees at Yankton with the Chicago, Milwaukee and St. Paul Railway, and with the elevation of the Missouri River determined by the Missouri River Commission.

	From Centerville.	Above the sea.
	Miles.	*Feet.*
Centerville, junction with the foregoing	0·0	1229
Vermilion River, low water, 1,183; grade	1·4	1204
Wakonda (a summit of grade)	10·5	1396
Volin	15·8	1181
James River, low water, 1,164; grade	24·3	1180
Yankton	28·5	1206
Missouri River here, extreme low and high water, about	28·5	1157–1198

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY.

[From profiles in the office of T. P. Gere, superintendent, and C. W. Johnson, engineer, St. Paul.]

EASTERN DIVISION, FROM ST. PAUL TO EAU CLAIRE.

Referred to sea level by the elevation of the Mississippi River at St. Paul, determined by United States engineers; agreeing with the determination of Lake St. Croix by United States engineers and with connecting railways at Eau Claire.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, extreme low and high water of the Mississippi River	0·0	683–702
St. Paul, union depot	0·0	703
Junction with the St. Paul, Minneapolis and Manitoba Railway	1·3	775
Trout Brook, bed, 754; grade	1·4	781
East St. Paul	2·0	822
Bridge over the St. Paul and Duluth Railroad, grade	2·1	829
St. Paul and Duluth grade	2·1	809
Phalen's Creek, bed, 803; grade	2·1	829
Post's Station	2·9	847
Phalen's Creek, bed, 838; grade	3·0	853
Phalen's Creek, bed, 853; grade	3·4	871
Creek, bed, 892; grade	4·2	923
Top of ascent from the Mississippi River, cutting 15 feet; grade	5·8	988
Tamarack swamp, natural surface, 973; grade	6·3	978
Midvale	7·0	1007
Summit, cutting 10 feet; grade	7·8	1008
Oakdale	8·7	979
Lake Elmo Station	11·8	933
Lower Bass Lake (or Lake Elmo), water	11·8	886
Upper Bass Lake, water	11·8	900
Crossing road on east line of Oakdale township, grade	12·8	923
Lake, water, 913; grade	14·6	926
Summit, grade	15·2	929
Stillwater Junction, of branch to Stillwater	15·7	879
Lakeland Junction, Stillwater Branch of the Chicago, Milwaukee and St. Paul Railway	18·7	706
Lake St. Croix, ordinary stage of water, 672–674; extreme low and high water, 667–687; grade on the drawbridge	19·0	697
River Falls Junction, of branch to River Falls	19·2	697
Hudson	19·7	718
North Wisconsin Junction, of line to Bayfield and Duluth	22·2	872
Chapman	26·8	1011
Roberts	30·2	1037
Hammond	36·0	1102
Baldwin	39·4	1134
Woodville	43·8	1152
Hersey	48·6	1199
Wilson	51·0	1147
Knapp	55·8	926
Menomonie Junction, of branch to Menomonie	64·4	882
Red Cedar River, ordinary low water, 800; high water (1881), 816; grade	65·7	862
Rusk	69·1	902
Elk Mound	76·8	929
West Eau Claire	85·8	880
Chippewa River, ordinary low water, 770; high water (1884), 792; grade	87·3	848
Eau Claire	87·8	839

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

HUDSON TO BAYFIELD.

Referred to sea level by the elevations of the Mississippi River at St. Paul, of Lake St. Croix at Hudson, and of Lake Superior at Bayfield, determined by United States engineers. Compared with these elevations, the profile contains a discrepancy of 3 feet, which would make its north end too low. From Hudson to Clayton the elevations here given accord with those of St. Paul and Lake St. Croix; and thence northward, namely, from Turtle Lake (which agrees within 1 foot with the Minneapolis, Sault Ste. Marie and Atlantic Railway) to Bayfield, they accord with that of Lake Superior.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Hudson	19·7	718
North Wisconsin Junction, of line to Eau Claire and Chicago	22·2	872
Burkhardt's	25·0	925
Boardman	30·0	949
New Richmond	35·5	989
Orme's	40·2	1057
Deer Park	44·2	1062
Clear Lake Station	52·5	1197
Summit, grade	53·8	1250
Pineville	55·1	1249
Richardson	58·3	1197
Clayton	60·1	1203
Turtle Lake Station, at crossing of the Minneapolis, Sault Ste. Marie and Atlantic Railway	64·4	1257
Perley	67·9	1249
Comstock	71·5	1282
Sprague	73·5	1257
Cumberland	77·2	1241
Granite Lake Station	82·6	1314
Barronette	84·6	1373
Summit, grade	86·6	1444
Shell Lake Station	93·4	1242
Chicago Junction, of line to Eau Claire and Chicago	98·1	1086
Yellow River, water, 1,060; grade	98·9	1086
Spooner	99·3	1095
Chandler	101·5	1145
Superior Junction, of line to Duluth	106·3	1089
Veazie	107·7	1084
Ames	110·9	1099
Namekagon River, water, 1,131; grade	119·1	1145
Stinnett	119·7	1146
Hayward	125·5	1194
Namekagon River, water, 1,198; grade	128·2	1213
Phipps	130·3	1234
Cable	142·0	1367
Summit, grade	148·0	1430
Drummond	151·9	1307
Pratt's	160·2	1027
Forest City	163·7	914
White River, water, 903; grade	166·3	949
Mason	166·7	965
Ashland Junction, of branch to Ashland	179·2	657
Ashland, on this branch	183·4	666
Crossing the Wisconsin division of the Northern Pacific Railroad, near Ashland Junction	179·6	653
Washburn	187·8	655
Bayfield	200·4	616
Lake Superior, mean, 1871 to 1887	200·4	601·56

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

SUPERIOR JUNCTION TO DULUTH.

Agreeing at Gordon with the elevation of the St. Croix River, and at Duluth with that of Lake Superior, both determined by United States engineers.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Superior Junction, line to Bayfield	106·3	1069
Namekagon River, water, 1,037; grade	106·7	1076
Lake Side	117·5	1108
Totogatic River, water, 1,010; grade	123·0	1032
Gordon	131·2	1024
St. Croix River, water, 1,006; grade	131·3	1022
White Birch	139·3	1081
Summit, grade	143·3	1238
Hawthorne	150·0	1154
Aminicon River, water, 950; grade	156·4	983
South Range	161·4	768
Junction with the Northern Pacific Railroad	168·9	635
Superior	169·3	643
West Superior, junction with the Northern Pacific Railroad	172·8	622
St. Louis Bay, Lake Superior, water	172·8	602
Rice's Point, junction with the Northern Pacific Railroad	174·4	617
Duluth	176·7	605

EAU CLAIRE TO CHICAGO JUNCTION.

The elevation of Eau Claire is in accordance with the determination of the Mississippi River at St. Paul, and of Lake St. Croix; but all the series thence northward receives an addition of 3 feet to accord with Lake Superior.

	From Eau Claire.	Above the sea.
	Miles.	*Feet.*
Eau Claire, 87·8 miles from St. Paul	0·0	839
South Chippewa Falls	10·0	861
Chippewa River, ordinary low water, 843; high water (1884), 859; grade	10·7	869
Eagle Point	17·9	974
Bloomer	24·7	1013
Cartwright	33·2	1110
Chetek River, water, 1,031; grade	41·3	1046
Chetek	41·9	1054
Cameron Junction, Minneapolis, Sault Ste. Marie and Atlantic Railway	48·7	1100
Red Cedar River, water, 1,114; grade	56·1	1134
Rice Lake Station	56·5	1146
Bear Creek Station	64·0	1232
Summit, grade	68·5	1343
Chicago Junction, of lines to Bayfield and Duluth, 98·1 miles from St. Paul	79·6	1086

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

WESTERN (ST. PAUL AND SIOUX CITY) DIVISION.

The profile of this division gives elevations above high water at St. Paul. It therefore receives here a constant addition of 703 feet, the mean between Major Allen's determination of it (702) and that supplied by leveling from the Gulf of Mexico under the direction of Major Mackenzie (703·75). It agrees exactly or closely with connecting railways at Mendota, Shakopee, Merriam and Kasota Junctions, Mankato, Lake Crystal, Worthington, Sibley, and Sheldon.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, union depot	0·0	703
Mendota Junction, Chicago, Milwaukee and St. Paul Railway	5·6	717
Nicols	10·8	717
Hamilton	18·6	718
Eagle Creek, grade	20·6	712
Barden (Bloomington)	22·1	741
Shakopee	28·1	745
Same, crossing the Hastings and Dakota division of the Chicago, Milwaukee and St. Paul Railway	28·5	753
Summit, grade	30·1	757
Summit, grade	33·6	767
Merriam Junction, Minneapolis and St. Louis Railway	34·0	755
Jordan (formerly Brentwood Station)	39·0	752
Summit, grade	41·0	766
St. Lawrence	42·0	748
Belle Plaine	46·5	728
High water of the Minnesota River here	46·5	722
Blakely	50·9	731
Creek, bed, 716; high water (of the Minnesota River), 726; grade	51·0	731
Cut 29 feet deep in till, at Rocky Point, section 30, Blakely; grade	54·9	738
High water of the Minnesota River here	54·9	731
East Henderson	57·7	737
Le Sueur Creek, water, 727; grade	61·0	742
Le Sueur	62·4	756
High water of the Minnesota River here	62·4	742
Ottawa	68·6	793
East St. Peter	74·5	751
Shanaska Creek, water, 744; grade	75·8	782
High water of the Minnesota River here	75·8	753
Kasota Junction, Chicago and Northwestern Railway	77·4	803
Summit, cutting 4 feet; grade	79·3	840
Stony Creek, water, 783; grade	80·7	820
Mankato	85·6	794
Extreme low and high water of the Minnesota River here, determined by United States engineers	85·6	752–778
Van Brunt Slough, surface, 766; grade	86·9	792
Crossing the Mankato Branch of the Chicago, Milwaukee and St. Paul Railway	87·2	803
Blue Earth River, ordinary low and high water, 759–777; grade	87·8	798
South Bend	89·2	811
Minneopa Bridge, 68 feet above the water	90·6	866
Minneopa	90·8	874
Summit, grade	96·8	995
Lake Crystal, junction of Blue Earth Branch	98·5	997
Summit, cutting 7 feet; grade	103·4	1012
Iceland	105·3	1001
Madelia	109·3	1024
Watonwan River, low and high water, 982–992; grade	110·8	1001
South Fork of Watonwan River, low and high water, 985–994; grade	111·8	1002
Lincoln	116·7	1045

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY - Continued.

WESTERN (ST. PAUL AND SIOUX CITY) DIVISION—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. James	122·0	1076
Butterfield	130·1	1187
Mountain Lake Station	137·0	1303
Summit, cutting 6 feet; grade	140·9	1393
Bingham Lake Station	143·2	1423
Summit, cutting 6 feet; grade	144·3	1434
Windom	147·8	1356
Des Moines River, water, 1,334; grade	148·1	1353
Bluff Siding	149·7	1428
Wilder	154·0	1451
Little Des Moines Creek, water, 1,397; grade	156·5	1409
Heron Lake, water, 1,406; grade	159·0–159·5	1408
Heron Lake Station, junction of the Pipestone (or Black Hills) Branch	160·3	1420
Prairie Junction, crossing the Southern Minnesota division of the Chicago, Milwaukee and St. Paul Railway	164·0	1429
Brewster (Hersey)	170·0	1488
Elk Creek, water, 1,476; grade	171·5	1492
Junction of the Burlington, Cedar Rapids and Northern Railway	177·9	1590
Summit, cutting 4 feet; grade	178·2	1591
Worthington	178·4	1585
East Okabena Lake (maximum depth, 15 feet), water, 1,572; grade	178·6	1578
(West Okabena Lake (maximum depth, 25 feet), 1,575; Lake Ocheeda or Ocheyedan (maximum depth, in its northeast part, 20 feet), about 1,565 feet.)		
Sioux Falls Junction, of branch to Sioux Falls and Mitchell	181·8	1637
Summit, cutting 3 feet; grade, highest point on line from St. Paul to Sioux City	182·3	1657
Summit, cutting 5 feet; grade	184·6	1654
Bigelow	187·8	1634
State line; grade	188·3	1647
Summit, cutting 6 feet; grade	188·9	1650
Sibley, near crossing of the Burlington, Cedar Rapids and Northern Railway	195·9	1512
Ashton (St. Gilman)	202·3	1445
Floyd River, bed, 1,377; grade	210·7	1386
Sheldon, near crossing of the Iowa and Dakota division of the Chicago, Milwaukee and St. Paul Railway	211·9	1409
Hospers	220·0	1341
Creek, water, 1,314; grade	221·3	1328
Floyd River, water, 1,280; grade	228·1	1299
Alton (East Orange)	228·4	1305
Floyd River, water, 1,243; grade	234·9	1256
Seney	239·6	1224
Le Mars	244·2	1224
Same, junction with the Illinois Central Railroad	244·5	1230
Floyd River at Le Mars, water	244·5	1200

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

BLUE EARTH BRANCH.

This agrees with the corrected profile of the Chicago, Milwaukee and St. Paul Railway at Winnebago City.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Lake Crystal, junction with the Western (St. Paul and Sioux City) division, main line	98·5	997
Watonwan River, low and high water, 902 919; grade	102·8	949
Garden City	103·5	961
Summit, natural surface and grade	109·0	1027
Edgewood (Vernon Centre)	109·3	1022
Blue Earth River, water, 941; grade	110·3	989
Amboy	114·5	1042
Shelbyville	116·4	1055
Summit, natural surface and grade	116·5	1059
Winnebago City	122·8	1095
Crossing the Southern Minnesota division of the Chicago, Milwaukee and St. Paul Railway	123·1	1103
Blue Earth River, water, 1,049; grade	131·9	1072
Blue Earth City	132 3	1083
Coon Creek, water, 1,060; grade	134·3	1082
Elmore	141·6	1125
State line, grade	142·0	1122

PIPESTONE (OR BLACK HILLS) BRANCH.

Agreeing exactly or closely with other railways at Pipestone and Flandreau.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Heron Lake Station, junction with the Western division main line	160·3	1420
Dundee	168·5	1446
Lime Creek, bed, 1,450; grade	174·7	1473
Avoca	180 1	1536
Slayton	186·0	1608
Hadley	191·0	1692
Oksida or Beaver Creek, water	194·6	1627
Lake Wilson Station	196·0	1659
Summit, cutting 2 feet; grade	201·1	1851
Summit, cutting 1 foot; grade	201·9	1851
Line of Murray and Pipestone Counties, grade	202·5	1842
Woodstock	204·3	1825
Rock River, water	208·3	1648
Summit, natural surface	211·5	1788
Crossing the Burlington, Cedar Rapids and Northern Railway	215·1	1728
Pipestone	215·4	1723
Big Sioux River at Flandreau, above and below the dam	230·8	1523–1514
Prairie, 4 miles farther west	235·0	1675

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

SIOUX FALLS AND MITCHELL BRANCH.

Agreeing exactly or closely with connecting railways at Luverne, Sioux Falls, Salem, and Mitchell.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Sioux Falls Junction, Western division, main line	181·8	1637
Summit, cutting 6 feet; grade	184·5	1694
Little Rock River, water, 1,632; grade	187·4	1652
Rushmore	190·1	1668
Adrian	196·9	1541
Kanaranzi Creek, water, 1,502; grade	198·0	1514
Summit, cutting 5 feet; grade	199·5	1572
Magnolia (Drake)	203·8	1519
Elk Slough, surface, 1,455; grade	206·2	1472
Summit, cutting 15 feet; grade	207·1	1518
Warner	208·0	1465
Crossing the Burlington, Cedar Rapids and Northern Railway	210·0	1440
Rock River, water, 1,426; grade	210·3	1440
Luverne, junction of the Rock River Branch	211·1	1454
Summit, cutting 5 feet; grade	216·1	1546
Beaver Creek Station	219·4	1446
Beaver Creek, water, 1,388; grade	219·8	1399
State Line, grade	224·4	1386
Valley Springs	225·1	1395
Split Rock Creek, low and high water, 1,291–1,304; grade	230·6	1321
Brandon	232·0	1319
Big Sioux River, low and high water, 1,284–1,305; grade	232·4	1310
Terrace south of river, natural surface and grade	234·4	1366
Sioux Falls	240·3	1397
Crossing the Chicago, Milwaukee and St. Paul Railway	240·4	1401
Big Sioux River, low and high water, 1,383–1,388; grade. This is above the upper dam, that of the Cascade Mills (Emerson, Sherman & Co.).	240·5	1406
Summit, cutting 10 feet; grade	241·6	1474
Big Sioux River, water, 1,406; grade	243·4	1420
Skunk Creek, water, 1 452; grade	250·0	1468
Hartford	254·4	1564
Summit, cutting 3 feet; grade	261·2	1695
East Vermilion River, water, 1,458; grade	268·0	1472
Montrose	268·3	1474
Little Vermilion River, a branch of the East Vermilion River, water, 1,471, grade	269·5	1483
Summit, natural surface and grade	275·9	1589
Salem, junction with branch of the Dakota division, Chicago and Northwestern Railway	279·5	1520
Spencer	289·5	1387
Fulton	301·0	1332
James River, water	309·0	1207
Mitchell	311·8	1312
A preliminary survey northwestward from Salem supplies the following, which agree with the Chicago, Milwaukee and St. Paul Railway at Forestburg:		
West Vermilion River, water, Sec. 15, T 103, R. 55	281·0	1460
Wolf Creek, water, Sec. 20, T. 104, R. 56	290·6	1373
Fawn Lake, water, T. 105, R. 58	303·6	1323
Stony Creek, water, Sec. 25, T. 106, R. 60	313·0	1256
James River, water, Sec. 12, T. 106, R. 61, near Forestburg	320·2	1215
Prairie, 5 miles west of James River	325·0	1279

CHICAGO, ST. PAUL, MINNEAPOLIS AND OMAHA RAILWAY—Continued.

ROCK RIVER BRANCH.

Agreeing with the Burlington, Cedar Rapids and Northern Railway at Rock Rapids.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Luverne, junction with the Sioux Falls and Mitchell Branch	211·1	1454
Ash Creek Station	218·7	1399
State Line, grade	221·6	1377
Rock Rapids, near crossing of the Burlington, Cedar Rapids and Northern Railway	226·5	1347
Rock River, low and high water	231·0	1299–1314
Doon	238·9	1285
Rock River at the south line of Lyon County, Iowa, low and high water	240·2	1251–1269

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY.

[From profiles in the office of H. Fernstrom, engineer, St. Paul.]

ST. PAUL TO DUBUQUE AND CHICAGO.

Referred to sea level by the elevations of the Mississippi River at St. Paul and Dubuque, determined by United States engineers, and of Lake Michigan, determined by the United States Lake Survey, which require a subtraction of 5 to 7 feet, here made, throughout the profile; then agreeing exactly or closely with connecting railways at Empire, Randolph, Dodge Centre, Dubuque Junction, Taopi, New Hampton, and Oelwein.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
St. Paul, union depot	0·0	703
Mississippi River, low and high water, 683–702; grade	0·2– 0·5	710
West St. Paul, water tank	1·0	702
Inver Grove	7·7	718
Summit, grade	13·3	902
Rich Valley	15·8	860
Summit, grade	17·6	925
Vermilion River, bed, 836; grade	22·2	850
Empire	22·6	854
Crossing the Hastings and Dakota division of the Chicago, Milwaukee and St. Paul Railway	22·8	858
Little Vermilion River, bed, 849; grade	23·7	877
Hampton (a summit of grade)	26.7	980
Depression, grade	27·4	958
Summit, grade	28·0	980
Randolph, station and crossing the Wisconsin, Minnesota and Pacific (Minneapolis and St. Louis) and Chicago, Milwaukee and St. Paul Railways	32·8	876
Chub Creek, bed, 859; grade	33·0	873
Cannon River, bed, 848; grade	33·4	871
Stanton	36·4	920
Summit, grade	40·9	974
Dennison	41·4	967
Spring Creek, bed, 954; grade	41·7	964
Summit, grade	46·2	1185
Nerstrand	46·5	1182
Depression, grade	47·5	1145
Summit, grade	49·6	1212
North Branch of Zumbro River, bed, 1,070; grade	52·6	1139
Kenyon	53·0	1140

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

ST. PAUL TO DUBUQUE AND CHICAGO—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Summit, grade	55·6	1248
Skyberg	58·1	1194
Silver Creek (North Middle Branch of Zumbro River), bed, 1,153; grade	60·7	1176
West Concord	62·6	1232
Summit, grade	63·8	1275
Branch of Zumbro River, bed, 1,224; grade	65·3	1238
Summit, grade	66·0	1271
Eden	67·2	1215
South Middle Branch of Zumbro River, bed, 1,169; grade.	67·8	1181
Summit, grade	69·6	1250
Creek tributary to the South Middle Branch of Zumbro River, bed, 1,181; grade	70·4	1225
Dodge Centre, station and crossing the Chicago and Northwestern Railway	71·8	1292
Summit, grade	79·2	1362
Hayfield	81·1	1315
Dubuque Junction, branch to Lyle	82·4	1318
Red Cedar River, bed, 1,294; grade	83·1	1308
Sargent	87·5	1380
Summit, grade	89·4	1395
Depression, grade	91·2	1357
Renova	92·7	1387
Crossing the Southern Minnesota division, Chicago, Milwaukee and St. Paul Railway	93·6	1377
Summit, grade, highest on this line	94·3	1402
Rose Creek, bed, 1,328; grade	96·6	1352
Elkton	98·7	1382
Summit, grade	104·7	1392
Taopi	106·3	1342
Crossing the Iowa and Minnesota division, Chicago, Milwaukee and St. Paul Railway	106·5	1340
Summit, grade	108·5	1365
Bailey	113·1	1282
Woodman's Creek, bed, 1,240; grade	116·0	1263
Watson Creek, bed, 1,187; grade	120·6	1227
Riceville	121·0	1229
Lowther	125·6	1208
Elma	131·0	1182
Summit, grade	132·4	1238
Elk Creek, bed, 1,144; grade	134·1	1158
Altavista	134·9	1155
Summit, grade	137·0	120[illegible]
Devon	141·2	119[illegible]
Crossing the Iowa and Dakota division, Chicago, Milwaukee and St. Paul Railway	145·1	11[illegible]
New Hampton	145·7	11[illegible]
Boyd	150·0	11[illegible]
East Wapsipinicon River, bed, 1,058; grade	154·0	10[illegible]
Fredericksburg	154·6	10[illegible]
Summit, grade	157·7	1[illegible]
Sumner, station and junction of the Waverly Branch	164·3	1[illegible]
Creek tributary to the Wapsipinicon River, bed, 1,050; grade	165·3	1[illegible]
Summit, grade	167·8	1[illegible]
Depression, grade	170·3	1[illegible]
Westgate (a summit of grade)	172·0	1[illegible]
Otter Creek, bed, 1,030; grade	179·6	1[illegible]
Oelwein, station and junction of line to Des Moines, St. Joseph, and Kansas City	179·7	1[illegible]3
Crossing the Burlington, Cedar Rapids and Northern Railway	180·1	1[illegible]47

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

ST. PAUL TO DUBUQUE AND CHICAGO—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Summit, grade	184·4	1143
West Buffalo Creek, bed, 1,091; grade	185·1	1099
Stanley	185·4	1098
Summit, grade	187·4	1144
East Buffalo Creek, bed, 1,080; grade	188·5	1090
Aurora (a summit of grade)	190·0	1135
Lamont	194·7	1045
Summit, grade	197·7	1084
South Fork of Maquoketa River, bed, 970; grade	199·7	995
Dundee	200·0	1001
Mink Creek, bed, 991; grade	201·8	998
Summit, grade	204·2	1058
Thorpe	204·9	1047
Honey Creek, bed, 984; grade	206·2	994
Summit, grade	209·3	1078
Crossing the Chicago, Milwaukee and St. Paul Railway	209·9	1051
Oneida	210·3	1045
Almoral	214·5	978
East Branch of Plum Creek, bed, 957; grade	215·8	969
Summit, grade	218·0	1040
North Fork of Maquoketa River, bed, 929; grade	222·6	945
Dyersville	222·9	945
Summit, grade	228·5	1090
Farley	229·1	1068
Kidder	233·3	860
Graf	237·4	768
Durango	245·4	643
Dubuque, station and crossing the Chicago, Milwaukee and St. Paul Railway	253·2	611
Mississippi River, extreme low water (1864), 584·75; extreme high water (1880), 606·65; grade	253·7–254·0	622
Menominee	262·0	610
Portage Curve	267·2	608
Galena Junction	267·9	612
Aiken	269·0	611
Tunnel ½ mile long, natural surface above, 1,008; summit grade, at east end of tunnel	272·7–273·2	800
Tunnel Siding	274·0	763
Tronsdale	278·8	638
Apple River, bed, 614; grade	279·0	640
Elizabeth	282·0	785
Summit, grade	284·7	891
Depression, grade	285·8	845
Woodbine	286·9	870
Summit, grade	289·4	906
Rush Creek, bed, 788; grade	290·8	832
Stockton (a summit of grade, highest between the Mississippi and Lake Michigan)	294·3	1002
Kent	300·6	898
Yellow Creek Station	305·6	826
Ellis	311·0	821
Summit, grade	314·7	838
Crossing, 20 feet above the Chicago, Milwaukee and St. Paul Railway	316·0	800
Crossing, 20 feet above the Illinois Central Railroad	318·0	865
Dunbar	318·6	853
German Valley	324·5	810
Summit, grade	326·0	864
Melton	331·5	769
Crossing the Chicago, Milwaukee and St. Paul Railway	337 0	724
Byron	337·4	724
Walnut Creek, bed, 647; grade	340·0	698
Stillman Valley	341·9	721

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

ST. PAUL TO DUBUQUE AND CHICAGO—Continued.

	From St. Paul.	Above
	Miles.	*Fe*
Summit, grade	346·0	
Holcomb	346·7	
Crossing the Chicago, Burlington and Quincy Railway	347·0	
Lindenwood	350·3	
Killbuck Creek, bed, 747; grade	351·0	
Esmond	355·7	
Summit, grade	358·0	
Depression, grade	359 5	
Clare	361·4	
Summit, grade	363·7	
Kishwaukee River, bed, 815; grade	366·8	
Crossing the Chicago and Northwestern Railway	368·6	
Sycamore	368·8	
Richardson (a summit of grade)	374·0	
Summit, grade	379·7	
Lily Lake Station	379·9	
Wasco	383·9	
Fox River, bed, 676; grade	389·0	
St. Charles	389·5	
Crossing, 20 feet above the Chicago and Northwestern Railway	393·5	
Ingalton	394·6	
Du Page River, bed, 715; grade	396·1	
Gretna	399·6	
Summit, grade	400·0	
Depression, grade	403·6	
Lombard	404·7	
Crossing, 20 feet above the Chicago and Northwestern Railway	405·1	
Salt Creek, bed, 655; grade	407·4	
South Elmhurst	408·5	
Summit, grade	409·4	
Maywood	413·7	
Des Plaines River, bed, 600; grade	414·4	
Crossing the C., H. and R. Railroad	414·7	
Forest Home	414·9	
Crossing the Belt Line Railway	418·8	
Crossing the Chicago, Burlington and Quincy Railway.	419·6	
Crossing the Chicago and Northwestern Railway and the C., St. L. and P. Railroad	421·4	
Chicago, Polk Street Depot	425·0	
(Lake Michigan, February, 1888, 580; mean during the years 1860 to 1888, 581 feet.)		

HAYFIELD TO LYLE.

Agreeing with connecting railways at Austin and Lyle.

	From St. Paul.	Above t
	Miles.	*Fe*
Hayfield	81·1	
Dubuque Junction, of line to Dubuque and Chicago	82·4	
Red Cedar River, bed, 1,286; grade	83·0	
Summit, grade	84·5	
Waltham	85·9	
Red Rock	90·7	
Roberts Creek, bed, 1,219; grade	91·4	
Summit, grade	92·2	

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

HAYFIELD TO LYLE—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Crossing the Southern Minnesota division, Chicago, Milwaukee and St. Paul Railway	93·9	1230
Crossing the Iowa and Minnesota division, Chicago, Milwaukee and St. Paul Railway	96·7	1213
Red Cedar River, bed, 1,178; grade	97·3	1199
Austin	97·7	1197
Red Cedar River, bed, 1,169; grade	98·2	1197
Rose Creek, bed, 1,167; water, 1,171; grade	101·7	1191
Summit, grade	103·2	1217
Varco	103·9	1205
Summit, grade	105·4	1214
Depression, grade	107·9	1192
Summit, grade	108·9	1204
Lyle	109·1	1202
Crossing the Austin and Mason City line of the Chicago, Milwaukee and St. Paul Railway and junction with the Central Iowa Railway	109·2	1200

OELWEIN TO ST. JOSEPH.

To accord with the profile from St. Louis to Chicago, this receives here a uniform subtraction of 6 feet. It then gives the elevation of low water in the Missouri River at St. Joseph 4 feet higher than its determination by the Missouri River Commission, which latter is doubtless very nearly correct.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Oelwein, junction with line to Dubuque and Chicago	179·7	1036
Summit, grade	183·7	1063
Fairbank	186·8	1000
Little Wapsipinicon River, bed, 952; grade	187·6	971
Summit, grade	188·3	1002
Buck Creek, bed, 947; grade	189·3	961
Summit, grade	190·6	999
Wapsipinicon River, bed, 924; grade	191·8	944
Dunkerton	194·8	945
Summit, grade	195·9	993
Dewar	199·4	889
Crossing, 20 feet above the Illinois Central Railroad	204·9	870
East Waterloo	205·4	843
Red Cedar River, bed, 827; grade	205·6	846
Crossing the Burlington, Cedar Rapids and Northern Railway	206·0	843
West Waterloo	206·7	845
Wilson's Junction	211·8	870
Hudson	214·9	883
Reinbeck	224·3	923
Crossing the Burlington, Cedar Rapids and Northern Railway	224·5	926
Berlin (a summit of grade)	231·4	1056
Four Mile Creek, bed, 997; grade	232·9	1008
Summit, grade	233·8	1050
Wolf Creek, bed, 925; grade	236·8	948
Crossing the Chicago and Northwestern Railway	236·9	948
Gladbrook	237·0	949
Summit, grade	242·1	1047
Green Mountain Station	245·8	994
Rockton	248·8	874

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

OELWEIN TO ST. JOSEPH—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Iowa River, bed, 845; grade	250·2	860
Crossing the Chicago and Northwestern Railway	253·1	872
Marshalltown (a summit of grade)	253·7	895
Crossing the Chicago and Northwestern and the Central Iowa Railways	254·1	887
Summit, grade	258·6	1000
Luray (a depression of grade)	260·0	934
Timber Creek, bed, 933; grade	261·6	948
Summit, grade	264·6	1055
Crossing the Central Iowa Railway, State Centre Branch.	265·2	1047
Crossing, 20 feet above the Chicago, Milwaukee and St. Paul Railway	266·5	1054
Melbourne	266·9	1040
North Skunk River, at water tank, bed, 887; grade	272·7	907
Summit, grade	275·1	1009
Baxter	276·0	998
Ira	280·8	826
Depression, grade	283·1	806
Indian Creek, bed, 796; grade	284·5	813
Mingo	285·1	819
Summit, grade	287·8	936
Valaria	290·0	848
Skunk River, at water tank, bed, 785; grade	291·4	802
Santiago	293·0	832
Summit, grade	297·0	970
Bondurant	297·8	963
Berwick (depression of grade at Four Mile Creek)	303·0	845
Summit, grade	305·1	934
Redhead	309·1	805
Crossing the Chicago, Rock Island and Pacific, the Wabash, St. Louis and Pacific, and the Chicago, Burlington and Quincy Railways	310·1	787
Des Moines River, bed, 769; grade	311·0	795
Crossing the Des Moines, Osceola and Southern Railroad.	312·2	794
South Des Moines	312·4	795
Millman	316·0	830
Pleasant Ridge Station	320·3	965
Summit, grade	322·8	977
Badger Creek, bed, 806; grade	326·2	828
Lida	327·2	848
Summit, grade	330·0	947
Crossing the Chicago, Rock Island and Pacific Railway	331·9	856
Middle River, bed, 810; grade	332·4	840
Sylvan	333·4	842
Hanley	339·7	883
Peru	346·4	939
Barney	353·4	1047
Lorimor	357·9	1224
Summit, grade	359·8	1232
Monette	361·1	1227
Grand River, bed, 1,027; grade	365·0	1059
Talmage	365·5	1072
Crossing, about 30 feet above the Chicago, Burlington and Quincy Railway	366·3	1078
Afton Junction (a summit of grade)	368·4	1162
Twelve Mile Creek, bed, 1,051; grade	370·0	1115
Arispe (a summit of grade, highest on this line)	373·6	1268
Shannon City	378·1	1139
Knowlton	384·7	1093
Crossing the H. and S. Railroad	385·6	1086
Benton	393·9	1051
Squirrel Creek, bed, 1,022; grade	394·2	1050

CHICAGO, ST. PAUL AND KANSAS CITY RAILWAY—Continued.

OELWEIN TO ST. JOSEPH—Continued.

	From St. Paul.	Above the sea.
	Miles.	*Feet.*
Maloy (a summit of grade)	397·3	1116
Blockton	403·0	1074
Line between Iowa and Missouri, grade	407·6	1061
Iona	407·9	1063
Sheridan	413·3	1037
Parnell City	418·8	1023
Summit, grade	419·7	1053
Platte River, bed, 968; grade	424·2	997
Ravenwood	425·5	1015
Conception	430·8	982
Crossing, about 20 feet beneath the Wabash, St. Louis and Pacific Railway	431·4	972
Guilford	439·0	941
Depression, grade	442·0	922
Cawood	442·8	935
Rea	446·6	1064
Summit, grade	446·8	1068
One Hundred and Two Mile River, bed, 874; grade	450·7	904
Depression, grade	451·0	900
Summit, grade	455·8	1090
Savannah	456·1	1085
Dean (a depression of grade)	461·3	882
Summit, grade	463·7	985
Junction with the Kansas City, St. Joseph and Council Bluffs Railway	468·8	820
St. Joseph	469·0	820
Missouri River at St. Joseph, low water and zero of the Signal Service gauge on the pivot pier of the St. Joseph and Grand Island bridge	469·0	794
Same, extreme low water, determined by the Missouri River Commission	469·0	790

MINNEAPOLIS AND ST. LOUIS RAILWAY.

[From profiles in the office of Robert Angst, engineer, Minneapolis.]

MAIN LINE.

This agrees with connecting railways at Chaska, Merriam Junction, Waterville, Waseca, Albert Lea, Madison, Britt, Livermore, and Fort Dodge.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Minneapolis, union depot	0·7	810
Same, depot of this railway, Third street and Fourth avenue northwest	0·0	826
Cedar Lake, low and high water, 857–862; grade	3·0	865
Bass Lake, water, 878; grade	4·5	886
Summit, cutting 12 feet; grade	5·5	918
Marsh, surface, 890; grade	7·5	895
Minnehaha Creek, water, 895; grade	7·8	907
Summit, cutting 14 feet; grade	8·2	928
Hopkins, junction of the Pacific division	8·7	921
Cut, 18 feet deep; grade	9·5	911
Shady Oak Lake, low and high water, 905–908; grade	10·6	910
Mud Lake, water, 900; grade	11·1	903
Summit, cutting 8 feet; grade	11·3	923
Glen Lake, surface of marsh, 905; grade	11·5	908

MINNEAPOLIS AND ST. LOUIS RAILWAY—Continued.

MAIN LINE—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Summit, cutting 18 feet; grade	11·6	918
Island Lake, water, 892; grade	12·7	904
Summit, natural surface and grade	12·9	914
Purgatory Creek, bed, 831; grade	14·1	855
Eden Prairie	15·2	884
Summit, cutting 8 feet; grade	16·5	902
Bradford Lake, water, 866; grade	18·0	874
Summit Station; cut 30 feet deep, on the line between Hennepin and Carver Counties, grade	18·7	876
Ravine, bottom, 772; grade	19·1	847
Same, bottom, 738; grade	20·1	803
Foot of the Minnesota River bluff, grade	22·0	754
Chaska, crossing the Hastings and Dakota division of the Chicago, Milwaukee and St. Paul Railway	22·7	728
Carver	24·7	722
Minnesota River, low water, 690; grade	24·9	728
Merriam Junction, crossing the St. Paul and Sioux City division of the Chicago, St. Paul, Minneapolis and Omaha Railway	27·2	755
Jordan	32·3	755
Sand Creek:		
Water, 753; grade	32·7	768
Water, 762; grade	32·9	777
Water, 780; grade	33·2	788
Water, 802; grade	33·8	810
Water, 821; grade	34·5	831
Helena	36·3	888
Sand Creek, water, 864; grade	36·6	874
Raven Stream, water, 868; grade	36·8	883
New Prague	42·6	975
Montgomery	50·0	1065
Mulford's Siding	54·6	1062
Crossing the town-line road between Montgomery and Kilkenny	54·9	1058
Lake Dora, high water, 1,042; grade	55·8	1046
Cannon River, water, 1,040; grade	56·9	1047
Kilkenny	58·6	1058
Little Cannon River, water, 1,021; grade	59·1	1039
Summit, highest natural surface on this line, 1,091; grade	62·3	1072
Summit, highest grade	63·0	1082
Cannon River, low water, 996; grade	65·0	1006
Lakes Tetonka and Sakata, low and high water	65·0	996–1002
Waterville, junction of the Wisconsin, Minnesota and Pacific Railway	65·4	1010
Crossing road on line of Le Sueur and Waseca Counties	67·0	1051
Palmer Siding (Iosco)	69·7	1148
Summit, cutting 14 feet; grade	70·3	1156
Loon Lake, water, 1,136; grade	75·7	1140
Crossing the Winona and St. Peter division of the Chicago and Northwestern Railway	76·0	1156
Waseca	76·2	1153
Creek in Sec. 8, Otisco, water, 1 078; grade	81·2	1084
Otisco	83·2	1148
Le Sueur River, water, 1,117; grade	84·8	1130
New Richland	88·7	1180
Hartland	94·9	1251
Summit and highway crossing, grade	99·1	1320
Manchester	100·9	1264
Summit, grade	106·4	1240
Albert Lea, junction with the Burlington, Cedar Rapids and Northern Railway	108·0	1230

MINNEAPOLIS AND ST. LOUIS RAILWAY—Continued.

MAIN LINE—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Crossing the Southern Minnesota division of the Chicago, Milwaukee and St. Paul Railway	108·1	1228
Pickerel Lake, water, 1,241; grade	110·3	1257
Summit, grade	111·6	1290
Twin Lakes Station, water, 1,245; grade	115·0	1261
Creek at the State line, water, 1,268; grade	120·9	1274
Norman	121·4	1285
Summit, grade	122·9	1323
Lake Mills	127·2	1270
Summit, grade	128·3	1279
Lime Creek, water, 1,218; grade	130·4	1228
Pike Creek, water, 1,216; grade	133·6	1224
Leland (Benson's Grove)	136·0	1222
Forest City	141·7	1226
Summit, grade	142·5	1236
Madison, junction with branch of the Burlington, Cedar Rapids and Northern Railway	146·8	1214
Marsh, grade	149·4	1220
Summit, grade	151·4	1235
Iowa River, water, 1,208; grade	152·8	1217
Summit, grade	154·2	1247
Depression, crossing the Iowa and Dakota division of the Chicago, Milwaukee and St. Paul Railway	155·5	1213
Britt (a summit of grade)	156·3	1236
Depression, grade	159·3	1191
Summit, grade	161·3	1222
Boone River, water, 1,159; grade	166·7	1168
Corwith (a summit of grade)	167·5	1186
Prairie Creek, water, 1,128; grade	174·7	1142
Summit, grade	175·9	1175
Depression, grade	176·5	1158
Summit, grade	177·5	1176
East Fork of Des Moines River, water, 1,081; grade	180·5	1106
Livermore	181·6	1141
Summit, grade	183·1	1151
Bloody Run, water, 1,100; grade	183·8	1124
Summit, grade	187·4	1158
Humboldt	192·0	1095
East Fork of Des Moines River, water, 1,047; grade	195·6	1071
Beaver Creek, water, 1,096; grade	197·5	1120
Summit, grade	198·3	1152
Badger Creek, water, 1,129; grade	200·6	1136
Summit, grade	201·4	1162
Soldier Creek, water, 1,118; grade	205·0	1128
Summit, grade	206 2	1148
Fort Dodge, upper depot	209·3	1126
Junction with the Iowa division of the Illinois Central Railroad	210·9	1126
The following are from Gannett's Dictionary of Altitudes:		
Fort Dodge, passenger station of the Illinois Central Railroad	.....	1032
Same, of the Minneapolis and St. Louis and Des Moines and Fort Dodge Railroads	.....	1015
Low water of the Des Moines River here is approximately	.....	1000

MINNEAPOLIS AND ST. LOUIS RAILWAY—Continued.

WISCONSIN, MINNESOTA AND PACIFIC RAILWAY, RED WING TO WATERVILLE AND MANKATO.

(Operated by the Minneapolis and St. Louis Railway Company.)

This agrees with connecting railways at Randolph, Northfield, Faribault, Waterville, and Mankato.

	From Red Wing.	Above the sea.
	Miles.	*Feet.*
Red Wing	0·0	708
Crossing Main street, Red Wing	0·2	711
Hay Creek, bed, 671; grade	1·1	693
Spring Creek, bed, 672; grade	2·7	692
Belle Creek, bed, 698; grade	9·4	709
Belle Creek Station	10·1	709
Cannon Falls	20·7	816
Cannon River, water in pond above the lower dam, Cannon Falls, 783; grade	21·0	812
Line of Goodhue and Dakota Counties, grade	22·2	843
Crossing the Chicago, St. Paul and Kansas City Railway	26·9	876
Chub Creek, low and high water, 864–869; grade	27·3	876
Cascade (Granville)	28·1	895
Waterford	33·8	905
Line of Dakota and Rice Counties, grade	34·8	899
Crossing the Cannon Falls line of the Chicago, Milwaukee and St. Paul Railway	35·3	912
Northfield	35·9	912
Cannon River, ordinary stage of water above the Northfield dam, 902; high water	.....	908
Dundas	38·8	928
Wolf Creek, water, 927; grade	40·2	944
Cannon River, low and high water, 956–962; grade	48·5	968
Faribault	49·0	973
Crossing the Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul Railway	49·5	983
Fair Ground	50·2	978
Junction of spur track to the Polar Star Mill	50·5	981
Warsaw	56·5	1009
Cannon River, water, 977; grade	57·4	986
Morristown	59·5	1010
Cannon River, low and high water, 996–1,002; grade	59·8	1010
Summit, cutting 11 feet; grade	62·0	1058
Line of Rice and Le Sueur Counties, grade	63·3	1032
Waterville, junction with the Minneapolis and St. Louis Railway, main line	65·8	1010
Elysian	71·7	1049
Madison Lake Station	78·7	1049
Eagle Lake Station	83·9	1011
Mankato	93·5	778

MINNEAPOLIS AND ST. LOUIS RAILWAY—Continued.

PACIFIC DIVISION.

(The portion from Hopkins to Morton is owned by the Minneapolis and St. Louis Railway Company; and the portion thence westward is operated by this company under a lease from the Wisconsin, Minnesota and Pacific Railway Company.)

The profile agrees with connecting railways at Excelsior, Norwood, Hanley Falls, and Watertown.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Hopkins, junction with the main line	8·7	921
Minnetonka Mills	11·7	936
Tamarack Marsh, bottom of mud, 880; grade	14 5	909
Hotel, St. Louis depot	15·8	943
Lake Minnetonka, Carson's Bay, water, 928, 18 feet deep; grade	16·0	933
Solberg point, grade on drawbridge and at crossing of the Hutchinson Branch of the St. Paul, Minneapolis and Manitoba Railway	17·9	938
Excelsior	18·9	947
Park Junction	20·3	938
Victoria	24·8	965
Windmill and tank	30·1	966
Waconia	31·5	986
Marsh, surface, 978–980; grade	34·0–34·7	981
Young America	39·1	993
Crossing the Hastings and Dakota division of the Chicago, Milwaukee and St. Paul Railway	40·2	976
Norwood	40·3	977
Hamburg	43·8	1000
Line of Carver and Sibley Counties, grade	45·0	995
Green Isle	48·1	1001
Arlington creek, water, 968; grade	53·7	984
Arlington	54·3	995
Rush River, outlet of Titlow Lake, water, 981; grade	59·7	986
Gaylord	62·3	993
Winthrop	69·3	1016
Rush River, water, 1,023; grade	73·5	1030
Gibbon	77·4	1016
Line of Sibley and Renville Counties, grade	82·2	1046
Mud Creek, bed, 1,022; grade	84·2	1038
Fairfax	86·9	1041
Fort Creek, water, 1,013; grade	89·5	1020
Three Mile Creek, water, 1,015; grade	90·2	1024
Franklin	94.9	1005
Purgatory Creek, bed, 966; grade	95·4	997
Johnson's Creek, bed, 941; grade	95·8	983
Thompson's Creek, bed, 871; grade	96 5	938
Campbell's Creek, bed, 868; grade	97·0	913
Birch Cooley, bed, 827; water, 832; grade	98 7	837
Morton	100·4	841
Minnesota River, bed, 805; ordinary low water, 814; high water (1881), 836; grade	100·7	842
North Redwood	106·2	855
Redwood River, bed, 826; water, ordinary stage, 831; grade	106·7	859
Top of river bluff, natural surface and grade	110·4	1028
Delhi	112·8	1022
Summit, cutting 3 feet; grade	121·9	1087
Echo	122·9	1080
Wood Lake Station	129·2	1059
Hanley Falls, near crossing of the Willmar and Sioux Falls (St. Paul, Minneapolis and Manitoba) Railway	134·3	1047
Yellow Medicine River, bed, 1,011; water, ordinary stage, 1,017; high water, 1,032; grade	134·7	1042

MINNEAPOLIS AND ST. LOUIS RAILWAY—Continued.

PACIFIC DIVISION—Continued.

	From Minneapolis.	Above the sea.
	Miles.	*Feet.*
Hazel Run Station	140·6	1057
Clarksfield	145·7	1084
Outlet of Muddy Lake, water, 1,046; grade	148·8	1054
Boyd	152·2	1050
East Branch of Lac Qui Parle River, bed, 1,028; high water, 1,037; grade	160·4	1052
West Branch of Lac Qui Parle River, bed, 1,029; high water, 1,047; grade	161·3	1054
Dawson	161·5	1054
Madison	170·4	1095
Marietta	181·5	1128
West line of Minnesota; grade	183·1	1146
Revillo	189·0	1208
South Fork of Yellow Bank River, trestle bridge, 56 feet high, grade	192·0	1340
Wilson	192·6	1366
Trestle bridge, 61 feet high; grade	196·9	1551
Lone Tree Lake, water, 1,880; grade	203·7	1882
Troy	205·5	1885
Summit, cutting 2 feet; grade	209·5	1995
Waverly	211·9	1992
Summit of the Coteau des Prairies, natural surface and grade	212·7	2000
Watertown, junction with the Burlington, Cedar Rapids and Northern Railway	222·1	1738
Same, passenger station (with Burlington, Cedar Rapids and Northern Railway)	222·3	1734

BURLINGTON, CEDAR RAPIDS AND NORTHERN RAILWAY.

[From H. F. White, engineer, Cedar Rapids.]

The notes of this entire railway system, as received from Mr. White, are found to require a subtraction of 20 feet, which is here made uniformly throughout its several divisions and branches, excepting at Plymouth Junction and thence to Albert Lea, where the subtraction required and here made is 18 feet.

BURLINGTON TO ALBERT LEA.

Referred to sea level by the elevation of the Mississippi River at Burlington, determined by United States engineers, and agreeing with connecting railways and other branches of this system at Linn Junction, Vinton, Plymouth Junction, and Albert Lea.

	From Burlington.	Above the sea.
	Miles.	*Feet.*
Burlington, extreme low and high water of the Mississippi River	0·0	510·77–531
Burlington, union depot	0·0	533
Latty	8·7	733
Sperry	11·6	757
Mediapolis	15·3	779
Linton	19·9	771
Morning Sun	22·7	745
Wapello	29·3	588
Bard	35·2	599
Columbus Junction	40·6	595
Iowa River, water	41·2	578

BURLINGTON, CEDAR RAPIDS AND NORTHERN RAILWAY—Continued.

BURLINGTON TO ALBERT LEA—Continued.

	From Burlington.	Above the sea.
	Miles.	*Feet.*
Port Allen	44·6	612
Cone	47·6	618
Nichols	55·0	638
West Liberty	61·7	673
Centerdale	67·1	725
West Branch Station	69·8	718
Oasis	73·3	800
Elmira	74·8	751
Morse	77·5	763
Summit, grade	79·3	862
Solon	82·3	794
Ely	89·4	741
Red Cedar River, water	96·5	705
Cedar Rapids	98·1	732
Linn Junction, of the Decorah Branch	102·3	756
Red Cedar River, water	103·0	728
Palo	108·0	751
Shellsburg	112·0	774
Vinton, junction of the Watertown line	121·0	810
Mount Auburn	128·9	863
La Porte	135·1	812
Washburn	143·3	827
Waterloo	150·6	841
Cedar Falls	156·4	854
Norris	159·8	864
Winslow	164·7	884
Shellrock	172·0	921
Clarksville	179·0	924
Greene	190·0	924
Marble Rock	195·7	1002
Rockford	203·7	1021
Nora Junction, Iowa and Dakota division of the Chicago, Milwaukee and St. Paul Railway	210·0	1062
Rock Falls	216·6	1104
Plymouth Junction, Austin and Mason City line of the Chicago, Milwaukee and St. Paul Railway	219·7	1126
Manly Junction	225·0	1201
Northwood	236·0	1222
State Line Station	238·7	1232
Glenville	245·7	1235
Albert Lea, junction with the Minneapolis and St. Louis Railway	252·7	1230
Lake Albert Lea, water	252·7	1209

DECORAH BRANCH.

Agreeing at Oelwein with the Chicago, St. Paul and Kansas City Railway, and at Postville and Decorah with the Chicago, Milwaukee and St. Paul Railway.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Linn Junction, 102·3 miles from Burlington	4·2	756
Toddville	10·1	780
Centre Point	18·0	819
Walker	24·7	890
Rowley	31·3	990
Independence	39·1	921
Wapsipinicon River, water	41·0	886

BURLINGTON, CEDAR RAPIDS AND NORTHERN RAILWAY—Continued.

DECORAH BRANCH—Continued.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Hazleton	49·3	998
Crossing the Chicago, St. Paul and Kansas City Railway	53·0	1047
Oelwein	53·4	1049
Maynard	60·3	1106
Randalia	66·5	1106
Summit, grade	71·3	1211
West Union	74·6	1115
Brainard	81·2	919
Elgin	85·3	843
Turkey River, water	86·0	811
Clermont	88·6	866
Postville Junction	94·9	1062
Postville, on branch 3½ miles from last	98·4	1192
Castalia	98·7	1240
Ossian	104·0	1271
Nordness	111·0	1035
Crow Creek, water	116·5	846
Decorah	118·2	853

VINTON TO WATERTOWN.

Agreeing exactly or closely with connecting railways and branches of this system at Dow's, Livermore, Emmetsburg, Lake Park, Sibley, Luverne, Pipestone, Elkton, and Watertown.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Vinton, junction with the Albert Lea line, 121·0 miles from Burlington	22·9	810
Garrison	29·9	859
Dysart	38·9	968
Traer	47·2	916
Reinbeck	59·3	926
Morrison	63·3	947
Grundy Centre	68·7	976
Holland	71·3	995
Wells	76·4	1058
Cleves	84·9	1070
Abbott	86·8	1099
Robertson	89·9	1175
Iowa Falls	96·9	1107
Carleton	107·3	1150
Iowa River, low and high water, 1,126–1,136; grade	112·5	1138
Dow's Station, junction of the Madison Branch	112·9	1142
Galtville	119·1	1198
Clarion	126·5	1168
Goldfield	136·0	1108
Hardy	144·3	1129
East Fork of Des Moines River, water, 1,069; grade	151·0	1092
Livermore	152·6	1136
Bode	158·1	1150
West Bend	168·6	1197
Rodman	174·9	1193
Emmetsburg	184·5	1234
Des Moines River here, about	184·5	1190
Medium Lake, water, about 1,220; grade	185·3	1224
Des Moines River, low and high water, 1,212–1,228; grade	193·7	1233
Same, low and high water, 1,247–1,261; grade	206·0	1270

BURLINGTON, CEDAR RAPIDS AND NORTHERN RAILWAY—Continued.

VINTON TO WATERTOWN—Continued.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Estherville	207·0	1284
Des Moines River, low and high water, 1,254–1,268; grade	207·2	1291
Cut, 8 feet deep, grade	213·7	1498
Summit, cutting 3 feet, on the water-shed between the Mississippi and Missouri Rivers	217·0	1547
Depression, grade	221·5	1404
Spirit Lake Station	223·5	1457
Spirit Lake, water	223·5	1395
(Mean depth of Spirit Lake, about 15 feet; maximum, in north part, 55 feet.)		
(East and West Okoboji Lakes, 1,390. The maximum depth of the former, in its south part, is 20–25 feet; of the latter, also in its south half, 90–125 feet.)		
Little Sioux River, water, 1,387; grade	230·0	1397
Lake Park, junction of the Worthington Branch	234·0	1479
Ocheyedan	246·0	1551
Ocheyedan Creek, water, 1,467; grade	248·0	1479
Summit, cutting 2 feet; grade	253·4	1628
Sibley, near crossing of the Chicago, St. Paul, Minneapolis and Omaha Railway	257·5	1502
Otter Creek, water, 1,493; grade	258·3	1504
Little Rock River, water, 1,440; grade	265·0	1463
Summit, cutting 14 feet; grade	267·1	1513
Tom Creek, water, 1,481; grade	268·0	1493
State line, grade	271·4	1483
Ellsworth, junction of the Sioux Falls Branch	273·7	1445
Kanaranzi Creek, water, 1,410; grade	276·5	1422
Kanaranzi	279·3	1505
Rock River, water, ordinary and highest stages, 1,428–1,433; grade	286·7	1437
Luverne	287·2	1452
Trosky	305·0	1702
Pipestone	314·0	1725
Cazenovia	319·4	1670
Flandreau Creek, water, 1,598; grade	323·3	1620
Altoona	325·0	1693
Elkton, near crossing of the Chicago and Northwestern Railway	333·6	1742
Medary Creek, water, 1,650; grade	339·6	1656
Bushnell	343·6	1694
Deer Creek, water, 1,652; grade	344·5	1660
White	351·2	1778
Toronto	361·1	1994
Summit (crest of a spur of the Coteau des Prairies), grade	361·5	1999
Outlet of Clear Lake, water, 1,773; grade	374·8	1778
Clear Lake Station	375·3	1800
Durham	385·8	1936
Watertown, junction with the Wisconsin, Minnesota and Pacific (Minneapolis and St. Louis) Railway	399·4	1734

BURLINGTON, CEDAR RAPIDS AND NORTHERN RAILWAY—Continued.

MADISON BRANCH.

This agrees with connecting railways at Garner and Madison.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Dow's Station, junction with the Watertown line, 211 miles from Burlington	112·9	1142
Rowan	119·5	1205
Belmond	128·0	1184
Iowa River, water, 1,166; grade	129·2	1172
Goodell	133·5	1236
Iowa River, water, 1,182; grade	138·5	1189
Garner, crossing the Iowa and Dakota division of the Chicago, Milwaukee and St. Paul Railway	145·8	1209
Madison, junction with the Minneapolis and St. Louis Railway	154·3	1214

WORTHINGTON BRANCH.

Agreeing with the Chicago, St. Paul, Minneapolis and Omaha Railway at Worthington.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Lake Park, junction with the Watertown line, 332·1 miles from Burlington	234·0	1479
Round Lake Station	244·3	1553
Junction with the Chicago, St. Paul, Minneapolis and Omaha Railway, a half mile northeast of Worthington	253·2	1590
Worthington	253·7	1585

SIOUX FALLS BRANCH.

Agreeing with connecting railways at Rock Rapids and Sioux Falls.

	From Cedar Rapids.	Above the sea.
	Miles.	*Feet.*
Ellsworth, junction with the Watertown line, 371·8 miles from Burlington	273·7	1445
Rock River, low water	283·0	1320
Rock Rapids, near crossing of branch of the Chicago, St. Paul, Minneapolis and Omaha Railway	283·6	1345
Larchwood	297·6	1462
Granite	304·5	1407
Springdale	309·5	1400
Sioux Falls	316·3	1400

FREMONT, ELKHORN AND MISSOURI VALLEY RAILROAD.

[From J. E. Ainsworth, engineer, Omaha.]

These profiles are referred to sea level in accordance with the elevation of the Missouri River at Blair, determined by the Missouri River Commission.

MAIN LINE, FROM MISSOURI VALLEY, IOWA, TO CASPER AND SOUTH PASS, WYO

	From Missouri Valley.	Above the sea.
	Miles.	*Feet.*
Missouri Valley	0·0	1002
Missouri River near Blair, Nebr., ordinary low water, 988; grade	11·0	1055
Blair Summit, cutting 47 feet; grade	16·4	1229
Elkhorn River at Arlington, water, 1,149; grade	30·3	1164
Fremont	37·2	1193
Elkhorn River at Crowell, water, 1,254; grade	65·8	1272
Norfolk Junction	118·1	1516
Elkhorn River, water, 1,524; grade	122·2	1541
Elkhorn River north of Oakdale, water, 1,694; grade	149·7	1708
Elkhorn River west of Neligh, water, 1,750; grade	158·9	1763
Elkhorn River east of O'Neill, water, 1,941; grade	190·1	1951
Stuart	220·4	2151
Long Pine	250·8	2396
Long Pine Creek, water, 2,298; grade	251·9	2389
Plum Creek, water, 2,498; grade	273·0	2592
Thacher	300·5	2649
Niobrara River, water, 2,392; grade	303·8	2472
Valentine	306·8	2579
Crookston	318·0	2670
Gordon	397·1	3547
Bordeaux Summit, surface and grade the same	425·9	3888
Chadron	443·6	3360
White River at Dakota Junction, water, 3,207; grade	448·3	3245
Fort Robinson	472·8	3775
White River Summit, cutting 21 feet; grade	495·9	4865
Niobrara River near Van Tassell, water, 4,688; grade	507·7	4703
Van Tassell	508·5	4727
Niobrara River at Lusk, water, 4,984; grade	528·1	4999
Lusk	528·4	5007
Niobrara River, water, 5,226; grade	536·9	5236
Niobrara Summit, 2 miles east of Keeline, cutting 6 feet; grade	542·6	5340
Fisher	565·3	4752
Douglas	583·5	4810
North Platte River, water, 4,787; grade	586·2	4827
Fetterman Hill, cutting 50 feet; grade	590·5	4951
La Prele Creek, water, 4,883; grade	591·3	4917
Casper (terminus, 1889)	636·9	5118
The continuation of this survey gives the following:		
North Platte River at Casper, water	636·9	5100
Same, 5 miles west of Casper, water, 5,129; proposed grade	642·0	5152
Poison Spider Creek, water, 5,211; proposed grade	649·5	5242
Summit in Sec. 7, T. 31, R. 83, crossing the Rattlesnake Range, natural surface, 6,478; proposed grade	668·5	6464
Horse Creek, water, 5,961; proposed grade	678·8	5977
Sweet Water River in Sec. 13, T. 29, R. 89, water, 6,060; proposed grade	705·4	6071
Sweet Water River at Rongis, water, 6,310; proposed grade	730·4	6318
Sweet Water River at mouth of Sulphur Creek, water, 6,591; proposed grade	751·6	6599
South Pass (continental divide between the North Platte and Green Rivers), natural surface, 7,429; proposed grade	796·2	7414

FREMONT, ELKHORN AND MISSOURI VALLEY RAILROAD—Continued.

BRANCH TO THE BLACK HILLS.

	From Missouri Valley.	Above the sea.
	Miles.	*Feet.*
White River, at Dakota Junction, water, 3,207; grade..	448·3	3245
Horsehead Summit, cutting 3 feet; grade.....	461·5	3664
South Fork of the Cheyenne River, water, 2,918; grade.	493·0	2939
Buffalo Gap.....	499·2	3252
Hermosa.....	527·3	3295
Rapid City.....	547·3	3192
Sturgis	577·0	3467
Whitewood Creek, water, 3,592; grade	582·7	3602
Whitewood (terminus, 1889).....	583·7	3640
The continuation of this survey gives the following:		
Whitewood Creek, water, 4,498; proposed grade.....	592·8	4506
Deadwood	593·2	4545
Pennington	596·7	4972

ALTITUDES OF RIVERS.

ST. LAWRENCE RIVER SYSTEM.

	Feet above the sea.
Lakes on the Embarras River, where it intersects the Mesabi range, about	1415–1320
St. Louis River at the mouth of East Savanna River, about	1260
Same, head of rapids above Knife Falls	1175
Same, foot of Knife Falls	1159
Same, at the railroad bridge, Thomson, low and high water	997–1020
The following altitudes of the Laurentian Lakes are determined by the United States Lake Survey:	
Lake Superior (maximum depth, 1,026 feet), extreme low and high water, approximately, 599–604; mean, Nov. 1, 1870, to Jan. 31, 1888	601·56
(Low stages of these lakes were in 1796, 1810, 1819 (the lowest recorded), 1828, 1847, 1865, and 1879; and high stages in 1788, 1814, 1838 (the highest recorded), 1858, 1876, and 1882.)	
Lakes Huron (maximum depth, 750 feet) and Michigan (maximum depth, 870 feet), extreme low and high water, approximately, 578·5–584·0; mean, Jan. 1, 1860, to Dec. 31, 1875	581·28
("The mean surface of Lake Michigan above mean sea level at New York, as determined by the United States Lake Survey, is 581·28 feet. The mean surface of Lake Michigan above mean sea level at Biloxi, as determined by the Mississippi River Commission, is 580·83 feet."—Letter of A. Mackenzie, major U. S. engineers, Rock Island, Ill., Jan. 23, 1888.)	
Lake Erie (maximum depth, 210 feet), extreme low and high water, approximately, 570–575·5; mean, Jan. 1, 1860, to Dec. 31, 1875	572·86
Niagara River, at head of the rapids above Niagara Falls	567
Same, at brink of the American Falls	526–518
Same, at brink of the Canadian or Horseshoe Falls	512
Same, at foot of Niagara Falls	357
Same, at the lower suspension bridge	347
The foregoing notes of Niagara River are from L. Y. Schermerhorn in the Am. Jour. of Sci., third series, vol. 33, Apr., 1887, p. 280.	
Lake Ontario (maximum depth, 738 feet), extreme low and high water, approximately, 244·5–249; mean, Jan. 1, 1860, to Dec. 31, 1875	246·61

From Prof. J. W. Spencer's Elevations in the Dominion of Canada (Bull. U. S. Geological Survey, No. 6) are supplied the following notes of the St. Lawrence River:

	From Montreal.	Above the sea.
	Miles.	*Feet.*
Mouth of Lake Ontario, Kingston	178	246·61
Galop's Rapids Canal	111·6–101·0	239–223
Rapide Plat Canal	99·5– 95·5	223–208
Farran's Point Canal	85·0– 84·2	204–200
Cornwall Canal (Long Sault)	79·2– 67·7	200–151
Lake St. Francis	67·7– 35·0	151
Beauharnois Canal	35·0– 23·7	151– 67
Lake St. Louis, junction of the Ottawa and St. Lawrence Rivers	23·7– 8·5	67
Lachine Canal	8·5– 0·0	67– 23
St. Lawrence River at the Victoria Bridge, Montreal, bed, 15; ordinary low water and extreme high water (April 1886)	.....	33– 59
Lake St. Peter, mouth of the Richelieu or Sorel River, to which high tide reaches	.....	11

MISSISSIPPI RIVER SYSTEM.

[From leveling by United States engineers; from the Mississippi River Commission; and from railroad surveys.]

The Minnesota and Missouri River systems, tributary to the Mississippi, are separately presented.

MISSISSIPPI RIVER AND LAKES NEAR ITS SOURCE.

Southward to Grafton, Ill., from leveling by United States engineers, the portion from Cass Lake to St. Paul being done under the direction of Maj. C. J. Allen, St. Paul, and that from St. Paul to Grafton under the direction of Maj. A. Mackenzie, Rock Island, Ill. In the series southward from St. Paul to Grafton the stage of low water noted is that of 1864, being extreme low water. The average stage for the year is 5 to 7 feet higher. The stage of high water noted along the same distance (unless otherwise designated) is that of 1880, which was an exceptionally high flood, rarely or never exceeded, along the distance from Lake Pepin to Rock Island. South of Savanna, Ill., these elevations are determined from precise leveling between the Gulf of Mexico and Lake Michigan by the Mississippi River Commission. Continuing north from Savanna, the series supplied by Maj. Mackenzie, which is accepted without change, shows a discrepancy at St. Paul of 1·71 feet above the elevation determined there by Major Allen. Besides the elevations supplied by the United States engineers, others are added from railroad surveys or are inserted by estimation, these being distinguished below St. Paul to Grafton by inclosure in parentheses.

From Cairo southward these elevations are derived from leveling and gauge records of the Mississippi River Commission in report on "Stages of the Mississippi River from Cairo to Carrollton, 1887" (therein referred at each station to the zero of its gauge, with note of the elevation of the zero above the Cairo datum plane). Besides this publication, the secretary of the Commission supplied manuscript records of St. Louis and for the year 1887 at Cairo, Memphis, Natchez, and Carrollton. [Apparently an error of a few feet exists in the determination of the heights of gauges along the the lower part of the river, by which its lowest stage at Baton Rouge and southward falls slightly below mean sea level.]

	Feet above the sea.
Lake Itasca, Apr. 22, 1889 (according to leveling by Mr. J. V. Brower from a bench mark of the survey for extension of the Fosston Branch of the St. Paul, Minneapolis and Manitoba Railway)	1462
(The range of this lake between its lowest and highest stages since 1880 has not exceeded 8 inches. Its maximum depth in the southeast arm is about 80 feet. Elk Lake is 1 foot above Lake Itasca. The crest of the watershed 2 miles west and south is 150 to 250 feet above Lake Itasca, or about 1,600 to 1,700 feet above the sea.)	
Mississippi River at the proposed crossing of the St. Paul, Minneapolis and Manitoba Railway in Sec. 8, T. 145, R. 35, about 11 miles north of Lake Itasca	1373
Lake Pemidji	1355
Cass Lake	1300–1302
Mouth of Horn River	1298
Horn Lake	1309
Lake Winnebagoshish, also Little Winnebagoshish Lake, formerly.	1290–1293
Lake Winnebagoshish, as raised by dam of reservoir system	1298
(This dam is constructed with capacity to raise the lake to 1,304·3 feet, but to the close of the year 1887 the highest level to which it had been raised was 1,298 feet. It is not expected that it will be raised more than 1½ feet above that level during at least several years to come.)	
Lake in Secs. 3 and 10, T. 146, R. 26, on the East Branch of Cut Foot Sioux Creek	1298
Head of East Branch of Cut Foot Sioux Creek, 1 mile from Bow String Lake	1306
Height of land between Lake Winnebagoshish and Bow String Lake	1345
Bow String Lake, head of the Big Fork of Rainy River	1321
Head and foot of small rapids 3 miles below Little Winnebagoshish Lake	1288–1287
Mouth of Leech Lake River	1279
Ball Club Lake	1281
Mud Lake	1280–1283

	Feet above the sea.
Leech Lake, formerly	1293-1295
Same, as raised by dam of reservoir system	1297
(The maximum depth of Leech Lake, in its southwest bay, is about 100 feet.)	
Highest level to which it is expected that this lake may be raised within the next 5 years	1298·5
Stage of maximum capacity of the Leech Lake dam	1299·5
Portage Lake	1299
Height of land on trail from Leech Lake to Lake Winnebagoshish.	1324
Height of land south of Leech Lake, about half way to Fourteen Mile Creek	1500
Fourteen Mile Creek on road south from Leech Lake to Brainerd	1375
North Branch of Pine River at crossing of this road	1323
Pine River at crossing of this road	1274
Hay Creek at crossing of this road	1238
South Branch of Hay Creek at crossing of this road	1243
Lower Hay Lake, formerly	1225
(This lake is now raised by dam to 1,227.)	
White Fish Lake, formerly	1224
Same, as raised by Pine River dam at outlet of Cross Lake	1227
Highest level to which it is expected that Cross and White Fish Lakes may be raised within the next few years	1231
Stage of maximum capacity of the Pine River dam	1236·7
Pelican Lake	1211
Upper Gull Lake, above the dam	1200
Gull Lake	1194–1196
Cullen Lake	1196
Sylvan Lake	1201
Round Lake	1195–1196
Lake Hubert	1199
Long Lake	1200
Red Sand Lake	1201
Mississippi River at White Oak Point	1276
Same, mouth of Vermilion River	1273
Vermilion Lake	1278
Mississippi River at mouth of outlet of Pokegama Lake, formerly	1270
Pokegama Lake, formerly	1271
Same, as raised by dam of reservoir system	1275
Bass Lake	1279
Little Bass Lake	1283
Head of Pokegama Falls, formerly	1269
Same, as raised by dam of reservoir system, flowing Pokegama Lake	1275
Foot of Pokegama Falls, 900 feet from the last	1254
Head of Grand Rapids, 3½ miles below Pokegama Falls	1253
Foot of Grand Rapids, ½ mile from the last, at head of navigation of the Mississippi	1248
Mouth of Split Hand River	1236
Mouth of Sandy River, nearly the same level as Sandy Lake	1210
Mississippi River at Aitkin	1190
Mouth of Pine River	1177
Head and foot of Big Eddy Rapids, ½ mile long	1170–1167
Head and foot of Island Rapids, 3,000 feet long	1164–1162
French Rapids, between 3 and 4 miles above Brainerd, 4,000 feet long, about	1159–1154
Mississippi River at Brainerd, low and high water	1150–1167
Mouth of Crow Wing River, low and high water	1145–1163
Mouth of Nokasippi River, near Fort Ripley	1139
Head and foot of Conradi's Shoals, ½ mile long, 9 miles below Fort Ripley	1106–1104
Little Elk Rapids, 1 mile long, near the mouth of Little Elk River	1102–1095
Rapids about ¾ mile long, Little Falls	1090–1079
(A dam recently built here raises the river above these rapids to 1,099 feet, flowing back to the middle of the Little Elk Rapids. The head obtained by the Little Falls dam and canal is 20 feet, from 1,099 to 1,079.)	
Pike Rapids, ½ mile long	1067–1064

	Feet above the sea.
At upper end of island, McDougall's Rapids	1033
Mouth of Platte River	1026
(Platte River at the highway bridge, 1,035; at the railway bridge, 1,059.)	
Mouth of Little Rock River	1003
At Watab	1001
Watab Rapids, 800 feet long	1000–998
Mouth of Sauk River, above the dam at Sauk Rapids	988
At foot of breakwater, Sauk Rapids	980
At railroad bridge, St. Cloud, low water before the dam was built	965
Head and foot of St. Cloud dam, ¼ mile below the last	975–962
(The canal here, 900 feet long, gives a fall of 15 feet, from 975 to 960.)	
At St. Augusta and foot of the "Thousand Islands"	946
At Clearwater, low and high water	936–954
At head of Bear Island, about a mile east from the mouth of Silver Creek	920
At Monticello	891
At Elk River	851
Mouth of Crow River, Dayton	839
Mouth of Rum River, Anoka	825
Mouth of Rice Creek, Fridley	800
At Minneapolis, crest of St. Anthony's Falls, ordinary and highest stages	794–802
Same, under the stone arch bridge, low water	739–743
Same, at the lower end of Hennepin Island	738
Same, at the St. Paul and Northern Pacific Railroad bridge, 1 mile below the falls	720
At the short line bridge, Chicago, Milwaukee and St. Paul Railway, low and high water	709–724
At Fort Snelling bridge	690
Mouth of Minnesota River, low and high water	688–710
At St. Paul, extreme low water, 1864, and Dec. 3 and 4, 1878, 683·04; lowest stage in ordinary years, 685; high water, 1880, 697·94; extreme high water, Apr. 29, 1881, 702·04	683–702
[These elevations at St. Paul are Major Allen's determinations, to which the series thence southward, supplied by Major Mackenzie, would add 1·71 feet.]	
(At Red Rock, Minn., 6 miles below St. Paul, low water	680)
(At Newport, Minn., low water	679)
(At the mouth of Gray Cloud Slough, 6 miles above Hastings, low water	673)
(At Nininger, Minn., low water	672)
At Hastings, Minn., low and high water	670·50–687·30
(Same, extreme high water, 1881, about	690)
(Mouth of the St. Croix River, Prescott, Wis., extreme low and high water, about	667–687)
At Red Wing, Minn., low and high water	664·50–680·65
(Lake Pepin (maximum depth, near its south end, 60 feet) low and high water	664–680·5)
(At Read's Landing, Minn., low and high water	663·7–680·4)
At Wabasha, Minn., low and high water	661·60–681·32
(The record of a flood stage here slightly higher than at Red Wing above Lake Pepin is probably due to the inflow from the Chippewa River, which joins the Mississippi near Wabasha. See Geology of Minnesota, vol. 2, p. 26.)	
At Alma, Wis., low and high water	655·93–672·18
At Minneiska, Minn., low and high water	649·94–665·64
At Fountain City, Wis., low and high water	644·16–660·10
At Winona, Minn., low and high water	639·19–656·27
(At Trempealeau, Wis., low water	636)
(At Dresbach, Minn., low water	632)
At La Crosse, Wis., low and high water	627·99–643·49
At Brownsville, Minn., low and high water	622·10–637·81
(At the southeast corner of Minnesota, low and high water, about	616–634·5)
At Victory, Wis., low and high water	615·39–634·01
At Lansing, Iowa, low and high water	612·24–631·84

	Feet above the sea.
At Prairie du Chien, Wis., low water, 604·28; high water, 1881, 623·28; extreme high water, 1880, about 626·20	604·28–626·20
At North McGregor, Iowa, low and high water	603·97–625·97
(Mouth of the Wisconsin River, low and high water, about	603–625)
At Clayton, Iowa, low and high water	601·42–622·70
At Glen Haven, Wis., low and high water	599·75–619·70
At Cassville, Wis., low and high water	594·99–616·46
At Specht's Ferry, Iowa, low and high water	589·85–610·80
At Dubuque, Iowa, low and high water	584·75–606·65
At Bellevue, Iowa, low and high water	577·87–598·02
At Savanna, Ill., low and high water	572·12–591·75
At Fulton, Ill., low and high water	566·48–586·68
At Clinton, Iowa, low and high water	565·89–586·18
At Le Claire, Iowa, at the head of the Rock Island Rapids, low and high water	562·25–576·25
At Rock Island, Ill., at the foot of the rapids, 12 miles from Le Claire, low and high water	541·56–559·96
At Muscatine, Iowa, low water, 530·53; high water, 1881, 547·10	530·5–547
At Port Louisa, Iowa, low and high water	525·52–541·67
At New Boston, Ill., nearly opposite to the mouth of the Iowa River, low and high water	523·45–539·34
At Keithsburgh, Ill., low and high water	522·71–536·16
At Oquawka, Ill., low and high water	515·63–531·15
At Burlington, Iowa, low and high water	510·77–526·51
(Notes from William Steyh, city engineer, supply the following elevations in Burlington:	
Mississippi River, extreme high water, 1851 and 1881	531
Union depot	533)
At Appanoose, Ill., low and high water	502·36–518·09
At Fort Madison, Iowa, low and high water	501·87–517·59
At Montrose, Iowa, at the head of the Des Moines Rapids, low water, 500·09; high water, 1881, 511·38; high water, 1851, 513·66.	500–513
At Keokuk, Iowa, at the foot of the rapids, 8 miles from Montrose, low and high water	476·96–494·46
(Mouth of the Des Moines River, at the southeast corner of Iowa, low and high water, about	475·5–493)
At Alexandria, Mo., low water	474·51
(Same, extreme high water	496)
At Gregory's Landing, Mo., low and high water	471·64–488·09
At Canton, Mo., low and high water	466·19–479·39
At Quincy, Ill., low and high water	458·21–474·76
At Hannibal, Mo., low and high water	450·12–467·42
(Same, high water, 1851	472)
At Louisiana, Mo., low and high water	437·11–452·91
At Clarksville, Mo., low and high water	433·05–448·25
(Mouth of the Illinois River, low and high water, about	407–424)
(Same, extreme high water, about	435)
At Grafton, Ill., low and high water	405·46–422·43
Mouth of the Missouri River, extreme low and high water, approximately	395–435
At St. Louis, Mo., zero of gauge, 378·97; extreme low and high water, 1870 to 1887 (range 33·78 feet)	379·99–413·77
[Same, bed, 363, extreme low water, 379; high water, 1844 (range, 49 feet), 428.—Gannett's Dictionary of Altitudes.]	
St. Louis directrix	412·71

The lowest and highest stages of the river here during the years 1870 to 1887 were as follows:

1870, l. w., Dec. 24, 384·23; h. w., Apr. 16, 405·18.
1871, l. w., Dec. 21, 381·81; h. w., March 17, 400·79.
1872, l. w., Dec. 4, 380·72; h. w., June 12, 400·87.
1873, l. w., Nov. 30, 382·84; h. w., Apr. 11, 403·22.
1874, l. w., Dec. 31, 381·77; h. w., Mar. 22, 399·03.
1875, l. w., Jan. 3, 381·27; h. w., July 11, 407·72.
1876, l. w., Dec. 9, 385·77; h. w., May 10, 410·97.
1877, l. w., Oct. 4, 385·82; h. w., June 14, 405·57.
1878, l. w., Dec. 25, 384·62; h. w., June 15, 404·72.
1879, l. w., Dec. 26, 382·47; h. w., July 3, 400·12.
1880, l. w., Nov. 29, 381·77; h. w., July 12, 404·47.

Feet above the sea.

1881, l. w., Feb. 5, 386·52; h. w., May 6, 412·62.
1882, l. w., Dec. 18, 381·82; h. w., July 5, 411·17.
1883, l. w., Jan. 12, 383·42; h. w., June 26, 413·77.
1884, l. w., Jan. 5, 382·12; h. w., Apr. 9, 407·07.
1885, l. w., Dec. 15, 381·07; h. w., June 17, 406·07.
1886, l. w., Dec. 5, 380·42; h. w., May 13, 405·97.
1887, l. w., Dec. 27, 379·99; h. w., Apr., 399·52.
(At Fountain Bluff, Ill., low and high water..... 313–357)
(At Thebes, Ill., low and high water ..... 291–339)
Mouth of the Ohio River, Cairo, Ill., zero of gauge ..... 269·58
Extreme low and high water, 1871 to 1887 (range 52·17 feet) ..... 269·58–321·75
Cairo datum-plane,—21·26 feet (below mean tide in the Gulf of Mexico).
The lowest and highest stages of the river here during the years 1871 to 1887 were as follows:
1871, l. w., Dec. 26, 269·58.
1872, l. w., Dec. 6, 270·58; h. w., Apr. 19, 308·78.
1873, l. w., Oct. 16, 272·18; h. w., Feb. 26, 311·13.
1874, l. w., Nov. 13, 272·58; h. w., Apr. 26, 316·95.
1875, l. w., Jan. 26, 274·88; h. w., Aug. 8, 314·70.
1876, l. w., Dec. 29–31, 270·68; h. w., Apr. 6, 315·96.
1877, l. w., Jan. 1, 270·58; h. w., Apr. 15, 310·10.
1878, l. w., Oct. 22, 275·50; h. w., Apr. 29, 306·62.
1879, l. w., Oct. 10, 272·26; h. w., Dec. 31, 306·08.
1880, l. w., Nov. 29, 275·28; h. w., Mar. 22, 314·18.
1881, l. w., Jan. 7 and 9, and Sept. 9, 274·98; h. w., Apr. 20, 315·38.
1882, l. w., Dec. 19, 276·88; h. w., Feb. 26, 321·45.
1883, l. w., Sept. 30, 274·28; h. w., Feb. 27, 321·75.
1884, l. w., Dec. 10, 276·88; h. w., Feb. 23, 321·37.
1885, l. w., Oct. 20, 277·88; h. w., Jan. 26, 308·58.
1886, l. w., Nov. 11, 273·38; h. w., Apr. 19, 320·56.
1887, l. w., Dec. 31, 271·60; h. w., Mar. 9, 318·16.
At Columbus, Ky., and Belmont, Mo., zero of gauge..... 207·88
Extreme low and high water, 1882 to 1886 (range, 41·40 feet)..... 270·28–311·68
(Same, extreme low water, about..... 261)
The lowest and highest stages of the river here during the years 1882 to 1886 were as follows:
1882, l. w., not recorded; h. w., Feb. 26, 310·67.
1883, l. w., Sept. 30, 270·48; h. w., not recorded.
1884, l. w., Dec. 10, 272·73; h. w., Feb. 23, 311·68.
1885, l. w., Oct. 20, 273.79; h. w., Jan. 26, 301·93.
1886, l. w., Nov. 12, 270·28; h. w., Apr. 19, 310·45.
(At Hickman, Ky., extreme low and high water, about..... 257–303)
At New Madrid (Morrisson's Landing), Mo., zero of gauge..... 254·78
Extreme low and high water, 1879 to 1886 (range 41·67 feet)..... 254·61–296·28
The lowest and highest stages of the river here during the years 1879 to 1886 were as follows:
1879, l. w., Nov. 12, 254·61.
1880, l. w., Nov. 30, 256·98; h. w., Mar. 24, 289·48.
1881, l. w., Jan. 8, 254·78; h. w., not recorded.
1882, l. w., Dec. 19, 258·49; h. w., not recorded.
1883, l. w., Oct. 1, 256·50; h. w., not recorded.
1884, l. w., Dec. 10, 258·73; h. w., Feb. 24, 296·28.
1885, l. w., Oct. 21, 260·09; h. w., Jan. 26, 286·20.
1886, l. w., Nov. 13, 256·71; h. w., Apr. 20, 295·16.
At Cottonwood Point, Mo., zero of gauge ..... 229·36
Extreme low and high water, 1879 to 1884 (range, 37·80 feet) ..... 229·41–267·21
The lowest and highest stages of the river here during the years 1879 to 1884 were as follows:
1879, l. w., Nov. 16, 229·41.
1880, l. w., Nov. 30, 231·51; h. w., Mar. 25, 264·86.
1881, l. w., Jan. 8, 230·96; h. w., Apr. 24, 264·56.
1882, l. w., Dec. 20, 233·01; h. w., Feb. 28, 266·86.
1883, l. w., Oct. 1, 230·36; h. w., Feb. 28, 267·21.
1884, l. w., Dec. 10, 232·11; h. w., Feb. 25, 266·81,
At Fulton, Tenn., zero of gauge ..... 207·29
Extreme low and high water, 1879 to 1886 (range, 34·59 feet)..... 209·39–243·98

	Feet above the sea.
The lowest and highest stages of the river here during the years 1879 to 1886 were as follows:	
1879, l. w., Nov. 14, 209·39.	
1880, l. w., Nov. 1, 211·94; h. w., Mar. 26, 241·44.	
1881, l. w., Jan. 9, 211·33; h. w., Apr. 26, 241·56.	
1882, l. w., Dec. 20, 213·93; h. w., Mar. 1, 243·98.	
1883, l. w., Oct. 1, 211·97; h. w., Mar. 2, 243·58.	
1884, l. w., Dec. 11, 212·77; h. w., Feb. 25–29, 242·97.	
1885, l. w., Oct. 21. 213. 57; h. w., Jan. 28, 237·21.	
1886, l. w., Nov. 14, 211·15; h. w., Apr. 22, 242·65.	
At Memphis, Tenn., zero of gauge	182·71
Extreme low and high water, 1872 to 1887 (range, 36·25 feet)	181·76–218·01
The lowest and highest stages of the river here during the years 1872 to 1887 were as follows:	
1872, l. w., Dec. 25, 181·76; h. w., Apr. 24, 214·21.	
1873, l. w., Oct. 30, 183·71; h. w., Mar. 3, 215·21.	
1874, l. w., Nov. 16, 184·11; h. w., May 2, 216·71.	
1875, l. w., Jan. 27, 185·91; h. w., Aug. 16, 215·76.	
1876, l. w., Dec. 30, 183·91; h. w., Apr. 8, 216·79.	
1877, l. w., Jan. 2, 183·46; h. w., Apr. 29, 214·76.	
1878, l. w., Nov. 3, 185·61; h. w., May 2, 211·81.	
1879, l. w., Oct. 9–12, and Nov. 11, 183·76; h. w., Jan. 29, 210·81.	
1880, l. w., Oct. 31, 185·31; h. w., Mar. 24–29, 216·11.	
1881, l. w., Sept. 11, 184·81; h. w., Apr. 27, 216·01.	
1882, l. w., Dec. 21, 186·21; h. w., Mar. 6 and 9, 217·86.	
1883, l. w., Oct. 2, 184·61; h. w., Mar. 7, 217·46.	
1884, l. w., Dec. 11, 185·81; h. w., Mar. 2, 216·86.	
1885, l. w., Oct. 22, 186·86; h. w., Jan. 28, 211·96.	
1886, l. w., Nov. 15, 185·21; h. w., Apr. 28, 217·51.	
1887, l. w., Nov. 20, 183·91; h. w., Mar. 10, 218·01.	
At Mhoon's Landing, Miss., zero of gauge	160·22
Extreme low and high water, 1882 to 1884 (range, 37·80 feet)	162·62–200·42
The lowest and highest stages of the river here during the years 1882 to 1884 were as follows:	
1882, l. w., Dec. 22, 166·17; h. w., Mar. 8, 200·02.	
1883, l. w., Oct. 1, 162·62; h. w., Mar. 8, 200·42.	
1884, l. w., Dec. 12, 162·82; h. w., March 5, 199·10.	
At Helena, Ark., zero of gauge	140·72
Extreme low and high water, 1872 to 1886 (range, 48·10 feet)	140·72–188·82
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:	
1872, l. w., Dec. 26, 140·72; h. w., Apr. 26, 179·75.	
1873, l. w., Oct. 17–22, 144·72; h. w., Mar. 6, 180·72.	
1874, l. w., Nov. 16, 144·42; h. w., May 11, 186·54.	
1875, l. w., Jan. 28, 147·22; h. w., Apr. 13, 183·12.	
1876, l. w., Dec. 31, 143·72; h. w., Apr. 18, 185·57.	
1877, l. w., Jan. 4, 142·42; h. w., Apr. 30, 182·52.	
1878, l. w., Nov. 3, 147·97; h. w., May 3, 179·47.	
1879, l. w., Nov. 14, 144·82; h. w., Jan. 31, 177·97.	
1880, l. w., Nov. 3, 148·82; h. w., Apr. 1, 184·41.	
1881, l. w., Sept. 15, 146·97; h. w., May 14, 184·46.	
1882, l. w., Dec. 22, 149·32; h. w., Mar. 9, 187·92.	
1883, l. w., Oct. 1, 147·12; h. w., Mar. 8, 187·62.	
1884, l. w., Dec. 13, 147·97; h. w., Mar. 6, 187·72.	
1885, l. w., Oct. 23, 148·72; h. w., Jan. 30, 181·42.	
1886, l. w., Nov. 16, 143·72; h. w., Apr. 30, 188·82.	
At Glendale, Miss., zero of gauge	146·81
1880, l. w., not recorded; h. w., Apr. 3, 184·47.	
1881, l. w., not recorded; h. w., May 13, 184·71.	
At St. Louis Landing, Ark., zero of gauge	120·01
1884, l. w., Dec. 13, 134·71; h. w., Mar. 6, 168·21.	
At Sunflower Landing, Miss., zero of gauge	125·87
1883, l. w., Oct. 1–4, 131·17; h. w., Mar. 10, 167·62.	
At Malone's Landing, Miss., zero of gauge	133·70
Extreme low and high water, 1880 to 1882 (range, 31·02 feet)	132·30–166·32
The lowest and highest stages of the river here during the years 1880 to 1882 were as follows:	
1880, l. w., Nov. 3, 133·80; h. w., not recorded.	
1881, l. w., Sept. 19, 132·30; h. w., May 14, 164·60.	

Feet above the sea.

1882, l. w., Dec. 24, 133·80; h. w., Feb. 28, 166·32.
Mouth of White River, Ark., zero of gauge ..... 107·47
Extreme low and high water, 1872 to 1886 (range, 48·40 feet) ..... 107·47–155·87
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:
1872, l. w., Dec. 28, 107·47; h. w., Apr. 30, 147 67.
1873, l. w., not recorded; h. w., Apr. 25, 150 37.
1874, l. w., Nov. 16, 110·17; h. w., not recorded.
1875, l. w., Jan. 2-, 114·27; h. w., Apr. 16, 152·47.
1876, l. w., Dec. 26, 110·37; h. w., Apr. 8–15, 154·17.
1877, l. w., Jan. 8, 109·67; h. w., May 5, 152·07.
1878, records lacking.
1879, l. w., Oct. 14, 109·87; h. w., not recorded.
1880, l.w., Nov. 4, 114·47; h. w., Apr. 24, 154·02.
1881, l. w., Sept. 14, 112·97; h. w., May 15–18, 153·17.
1882, l. w., Dec. 23, 117·17; h. w., Feb. 28, 155·87.
1883, l. w., Oct. 3, 114·27; h. w., Mar. 9–12, 155·47.
1884, l. w., Dec. 13, 116·47; h. w., Mar. 7, 155·37.
1885, l. w., Oct. 24, 117·47; h. w., Jan. 24. 151·07.
1886, l. w., Nov. 15, 113·37; h. w., May 4, 155·67.
At Arkansas City, Ark., zero of gauge ..... 95·09
Extreme low and high water, 1880 to 1886 (range, 45·20 feet) ..... 96·89–142·09
The lowest and highest stages of the river here during the years 1880 to 1886 were as follows:
1880, l. w., Nov. 4, 100·99; h. w., Apr. 3, 140·94.
1881, l. w., Jan. 14, 96·89; h. w., May 17, 139·39.
1882, l. w., Dec. 23, 102·64; h. w., Feb. 28, 142·09.
1883, l. w., Oct. 3, 99·34; h. w., Mar. 11, 141·41.
1884, l. w., Dec. 13, 102·59; h. w., Mar. 8, 141·59.
1885, l. w., Oct. 25, 102·79; h. w., May 8, 137·69.
1886, l. w., Nov. 16, 98·09; h. w., May 5, 141·99.
At Greenville, Miss., zero of gauge ..... 86·74
Extreme low and high water, 1882 to 1886 (range, 37·48 feet)..... 90·94–128·42
The lowest and highest stages of the river here during the years 1882 to 1886 were as follows:
1882, l. w., Dec. 23, 94·09; h. w., Feb. 27, 128·42.
1883, l. w., Oct. 4, 92·36; h. w., Mar. 11, 127·14.
1884, l. w., Dec. 13, 94·64; h. w., Mar. 8, 127·84.
1885, l. w., Oct. 25, 95·04; h. w., May 8, 124·79.
1886, l. w., Nov. 16, 90·94; h. w., May 6, 127·91.
At Refuge, Miss., zero of gauge ..... 81·53
Extreme low and high water, 1879 to 1881 (range, 40·00 feet) ..... 83·83–123.83
The lowest and highest stages of the river here during the years 1879 to 1881 were as follows:
1879, l. w., Oct. 28, 83·83.
1880, l. w., Nov. 6, 85·03; h. w., Mar. 23–27, 123·83.
1881, l. w., Sept. 20, 85·13; h. w. May 18, 123·53.
At Wilson's Point, La., zero of gauge ..... 72·19
1884, l. w., Dec. 14, 78·69; h. w., Mar. 23, 110·00.
At Lake Providence, La., zero of gauge ..... 68·36
Extreme low and high water, 1872 to 1886 (range, 42·25 feet)..... 64·51–106·76
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:
1872, l. w., Dec. 29, 64·51; h. w., May 1, 103·51.
1873, l. w., Nov. 4, 69·27; h. w., May 28, 104·48.
1874, l. w., Nov. 16, 69·31; h. w., Mar. 22, 105·73.
1875, l. w., Nov. 12, 74·26; h. w., Apr. 19, 105·65.
1876, l. w., Dec. 31, 69·61; h. w., Apr. 13, 106·31.
1877, l. w., Jan. 1–3, 69·61; h. w., May 6, 104·18.
1878, l. w., Oct. 27 and Nov, 5, 72·11; h. w., Mar. 23, 104·16.
1879, l. w., Oct. 16, 68·91; h. w., Feb. 15, 104·36.
1880, l. w., Nov. 3, 73·56; h. w., Apr. 3, 106·41.
1881, l. w., Sept. 14–19, 71·36; h. w., Mar. 11, 104·53.
1882, l. w., Dec. 25, 74·26; h. w., Mar. 20, 106·68.
1883, l. w., Oct. 2, 72·56; h. w., Mar. 11–14, 104·83.
1884, l. w., Dec. 15, 73·91; h. w., Mar. 23, 106·76.
1885, l. w., Oct. 26, 74·76; h. w., May 10, 103·91.
1886, l. w., Nov. 19, 70·91; h. w., May 7, 106·27.

	Feet above the sea.
At Hay's Landing, Miss. (Point Lookout, La.), zero of gauge.....	64·79
Extreme low and high water, 1882 and 1884 (range, 35·94 feet)	67·57–103·51
1882, l. w., Nov. 3, 70·83; h. w., Mar. 20, 103·38.	
1884, l. w., Dec. 14, 67·57; h. w., Mar. 24, 103·51.	
At Vicksburg, Miss., zero of gauge.....	44·78
Extreme low and high water, 1872 to 1886 (range, 50·30 feet).....	43·48–93·78
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:	
1872, l. w., Dec. 30, 43·48; h. w., May 2, 84·28.	
1873, l. w., Jan. 1, 47·13; h. w., May 29, 85·38.	
1874, l. w., Nov. 16 and 21, 47·93; h. w., May 2–5, 90·48.	
1875, l. w., Nov. 14, 52·88; h. w., Apr. 21, 87·78.	
1876, l. w., Dec. 30, 48 83; h. w., May 10, 89·68.	
1877, l. w., Jan. 6, 47·03; h. w., May 8–13, 86·38.	
1878, l. w., not recorded; h. w., March 24–27, 85·73.	
1879, l. w., not recorded; h. w., Feb. 17, 84·23.	
1880, l. w., Oct. 27, 52·48; h. w., Apr. 8, 87·93.	
1881, l. w., Sept. 19, 48·43; h. w., Mar. 11, 86·63.	
1882, l. w., Nov. 4, 53·28; h. w., Mar. 20, 93·53.	
1883, l. w., Oct. 6, 47·68; h. w., Apr. 7, 88·58.	
1884, l. w., Dec. 15, 49·63; h. w., Mar. 25, 93·78.	
1885, l. w., Oct. 26, 49·68; h. w., May 11, 85·68.	
1886, l. w., Nov. 16, 44·78; h. w., May 8, 88·93.	
At St. Joseph, La., zero of gauge	31·48
Extreme low and high water, 1882 to 1884 (range, 40·95 feet)	35·43–76·38
The lowest and highest stages of the river here during the years 1882 to 1884 were as follows:	
1882, l. w., Nov. 5–11, 39·58; h. w., Mar. 20, 76·38.	
1883, l. w., Oct. 8, 35·68; h. w., Apr. 7., 73·38.	
1884, l. w., Dec. 16, 35·43; h. w., Mar. 24, 76·37.	
At Natchez, Miss., zero of gauge	15·57
Extreme low and high water 1872 to 1887 (range, 47·75 feet)	15·57–63·32
The lowest and highest stages of the river here during the years 1872 to 1887 were as follows:	
1872, l. w., Dec. 15, 15·57; h. w., May 2–5, 55·42.	
1873, l. w., Jan. 1, 16·52; h. w., May 30, 55·72.	
1874, l. w., Nov. 17, 18·27; h. w., Apr. 20, 61·17.	
1875, l. w., Jan. 1, 22·57; h. w., Apr. 25, 57·42.	
1876, l. w., Dec. 31, 18·47; h. w., May 15, 59·42.	
1877, l. w., Jan. 9, 16·97; h. w., May 30, 56·27.	
1878, l. w., Nov. 8, 21·92; h. w., Mar. 28, 54·77.	
1879, l. w., Oct. 18–22, 17·37; h. w., Feb. 17–20, 52·37.	
1880, l. w., Oct. 28, 22·87; h. w., Apr. 16, 59·07.	
1881, l. w., Sept. 21, 20·27; h. w., Mar. 16 and 19, 56·37.	
1882, l. w., Nov. 6–9, 25·27; h. w., Mar. 28, 63·32.	
1883, l. w., Oct. 6, 20·47; h. w., Apr. 8, 59·57.	
1884, l. w., Dec. 16, 23·37; h. w., Mar. 25, 62·97.	
1885, l. w., Oct. 27, 22·07; h. w., May 13, 56·77	
1886, l. w., Nov. 8, 18·37; h. w., May 10, 59·32.	
1887, l. w., Nov. 25, 16·92; h. w., Mar. 31, 59·77.	
Mouth of the Red River and head of the Atchafalaya River, Red River Landing, La., zero of gauge.....	2·59
Extreme low and high water, 1872 to 1886 (range 48·50 feet)	2·59–51·09
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:	
1872, l. w., Dec. 15, 2·59; h. w., May 6, 42·01.	
1873, l. w., Oct. 25, 4·84; h. w., June 12, 41·61.	
1874, l. w., Nov. 22, 4·49; h. w., Apr. 16, 49·59.	
1875, l. w., Jan. 1, 8·59; h. w., May 3, 43·04.	
1876, l. w., Dec. 30, 4·84; h. w., May 15, 48·00.	
1877, l. w., Jan. 8 and 10, 3·44; h. w., June 2, 43·14.	
1878, records lacking.	
1879, l. w., Oct. 24, 3·14; h. w., Feb. 19, 38·49.	
1880, l. w., Oct. 26, 8·69; h. w., Apr. 23, 46·64.	
1881, l. w., Sept. 21, 5·99; h. w., Apr. 6–9, 42·69.	
1882, l. w., Oct. 18, 11·69; h. w., Mar. 27, 51·09.	
1883, l. w., Oct. 7, 6·54; h. w., Apr. 9, 47·79.	
1884, l. w., Oct. 1, 8·89; h. w., Mar. 30, 49·89.	

Feet above the sea.

1885, l. w., Oct. 26, 9·29; h. w., Feb. 5, 44·55.
1886, l. w., Nov. 20, 5·34; h. w., May 31, 44·53.
At Port Hickey, La., zero of gauge (below mean tide)..... —7·58
Extreme low and high water, 1881 to 1884 (range 38.40 feet)..... 1·92–40·32
The lowest and highest stages of the river here during the years 1881 to 1884 were as follows:
1881, l. w., Sept. 11, 1·92; h. w., Apr. 6, 33·22.
1882, l. w., not recorded; h. w., Mar. 28, 40·32.
1883, l. w., not recorded; h. w., Apr. 9, 38·52.
1884, l. w., Dec. 3, 5·54; h. w., Mar. 29, 39·84.
At Baton Rouge, La., zero of gauge..... —1·20
Extreme low and high water, 1872 to 1886 (range 35·30 feet)..... —0·30–35·00
The lowest and highest stages of the river here during the years 1872 to 1886 were as follows:
1872, l. w., Dec. 22, —0·05; h. w., May 7, 28·45.
1873, l. w., Jan. 1, 1·12; h. w., June 17, 28·65.
1874, l. w., Nov. 21, 1·10; h. w., Apr. 16, 34·95.
1875, l. w., Jan. 1, 2·75; h. w., May 13, 28·55.
1876, l. w., Dec. 30, 0·50; h. w., May 8 and 15, 32·20.
1877, l. w., Jan. 9, —0·30; h. w., June 1 and 4, 28·45.
1878, l. w., Nov. 6, 2·10; h. w., Apr. 1, 26·95.
1879, l. w., Nov. 21–24, 0·80; h. w., Feb. 16, 24·90.
1880, l. w., Oct. 14 and 25, 2·80; h. w., Apr. 23, 32·00.
1881, l. w., Sept. 22, 1·70; h. w., Apr. 8, 28·85.
1882, l. w., Oct. 18, 4·98; h. w., Mar. 26, 34·75.
1883, l. w., Oct. 7, 1·90; h. w., Apr. 9, 33·88.
1884, l. w., Dec. 1, 4·05; h. w., Mar. 24, 35·00.
1885, l. w., Oct. 31, 3·45; h. w., May 11–16, 28·95.
1886, l. w., Nov. 20, 1·15; h. w., June 1, 30·90.
At Plaquemine, La., zero of gauge..... —0·20
Extreme low and high water, 1881 to 1884 (range 30·12 feet)..... 1·28–31·40
The lowest and highest stages of the river here during the years 1881 to 1884 were as follows:
1881, l. w., Sept. 6 and 10–13, 1·60; h. w., Apr. 3–9, 25·80.
1882, l. w., Oct. 15–18 and Nov. 10, 3·60; h. w., Mar. 21–27, 31·10.
1883, l. w., Oct. 7, 1·28; h. w., Apr. 9, 30·53.
1884, l. w., Oct. 1, 2·70; h. w., Mar. 24, 31·40.
At College Point, La., zero of gauge..... —0·02
Extreme low and high water, 1880 to 1884 (range 22·73 feet)..... 1·30–24·03
The lowest and highest stages of the river here during the years 1880 to 1884 were as follows:
1880, l. w., Nov. 2, 2·63; h. w., Apr. 21, 21·28.
1881, l. w., Aug. 27 and Sept. 19, 1·33; h. w., May 23, 19·45.
1882, l. w., Oct. 13 and Nov. 7, 2·46; h. w., Mar. 22, 23·10.
1883, l. w., Oct. 13, 1·43; h. w., Apr. 9, 23·38.
1884, l. w., Dec. 2, 1·30; h. w., Mar. 24, 24·03.
At Carrollton, La., zero of gauge..... —0·35
Extreme low and high water, 1872 to 1887 (range 17·55 feet)..... —1·95–15·60
The lowest and highest stages of the river here during the years 1872 to 1887 were as follows:
1872, l. w., Dec. 27, —1·95; h. w., May 6, 11·95.
1873, l. w., Nov. 20, —0·27; h. w., June 3, 12·58.
1874, l. w., Nov. 7, —0·15; h. w., Apr. 15, 15·60.
1875, l. w., Nov. 13, —0·25; h. w., May 4 and 15, 10·95.
1876, l. w., Dec. 30, —1·55; h. w., May 11, 12·35.
1877, l. w., Jan. 9, —1·75; h. w., June 8, 10·75.
(Dec. 17, 1876, to Jan. 24, 1877, the river ranged from —0·15 to —1·75 below mean sea level.)
1878, l. w., Nov. 22, —0·45; h. w., Mar. 21, 10·95.
1879, l. w., Nov. 24, —1·15; h. w., Feb. 20 and 22, 10·45.
1880, l. w., Nov. 2, —0·05; h. w., Apr. 23, 13·90.
1881, l. w., Sept. 10, —0·05; h. w., Apr. 12, 12·20.
1882, l. w., Nov. 8, 0.65; h. w., Mar. 27, 14·60.
1883, l. w., Oct. 4, 0·25; h. w., Apr. 9, 14·95.
1884, l. w., Dec. 2 and 5, —0·05; h. w., Mar. 18, 15·25.
1885, l. w., Oct. 24, 0·55; h. w., Jan. 22, 13·20.
1886, l. w., Nov. 27, —0·75; h. w., May 31, 13·45.

Feet above the sea

1887, l. w, Sept. 9, —0·80; h. w., Apr. 6, 14.15.

(Oct. 10–13, 1886, a great storm on the Gulf coast caused the river to rise at Carrollton to a maximum (Oct. 12) 3 feet above its normal level, which during 2 weeks preceding and the week following was about 1 foot above mean tide. The same storm caused the river to rise at Baton Rouge nearly 4 feet, from about 2·5 to 6·3 feet above the sea.)

At New Orleans, about 5 miles below Carrollton, and 100 miles above Port Eads, at the mouth of the Mississippi, the stages of the river are nearly the same as at Carrollton. In the Report of the Chief Signal Officer, 1886, p. 168, it is stated that the zero of the gauge at New Orleans (marking the low water of Dec. 30, 1876) is 1·50 feet below sea level, and that the extreme high water of 1874 (to which the city system of leveling is referred) was 14·67 feet above sea level. The range is thus about 1 foot less than at Carrollton, or approximately 16·50 feet.

Depth of the Mississippi River at New Orleans, 80 to 208 feet.

A letter from D. M. Brosnan, city surveyor of New Orleans, Apr. 2, 1888, contains the following notes from leveling:

Mean sea level	0·00
Lowest water in Lake Pontchartrain	—1·65
Highest water in Lake Pontchartrain	+4·33
Lowest water in Mississippi River	—0·77
Highest water in Mississippi River, 1882	+14·83
Highest water in Mississippi River, 1874	+14·63

"No data are at hand concerning tides in Lake Pontchartrain. The effect of tide at New Orleans in the river is about 3 inches."

RUM RIVER.

Mille Lacs, mainly 10 to 25 feet deep, at head of Rum River, ordinary stage, 1,251; extreme low and high water	1249–1254
(The maximum depth of Mille Lacs, in its southeast part, is about 100 feet.)	
Height of land between Mille Lacs and Snake River, about 2½ miles southeast from the lake on the trail	1299
Rum River at Milaca, 12 miles north of Princeton	1042
Mouth of the West Branch, at Princeton	950
Junction with the Mississippi, Anoka	825

ST. CROIX RIVER.

This and the Namekagon, Kettle, and Snake Rivers are from leveling by United States engineers, under the direction of Maj. Charles J. Allen, St. Paul, and from railroad surveys.

	Feet above the sea.
Springs at head of the South Branch of the Bois Brulé River	1068
Springs at head of the St. Croix River	1070
(These springs rise in the same marsh, 600 feet apart, the Bois Brulé River running north, the St. Croix south. An ancient watercourse exists here, about a mile wide, bordered by drift bluffs 75 feet high, with their crests 1,140 to 1,150 feet above the sea. It was the outlet of Lake Superior when the receding ice-sheet on the northeast, acting as a barrier to the present course of outflow, held this lake about 500 feet higher than now.)	
Upper St. Croix Lake	1011
St. Croix River at Gordon	1006
Same, low water, above and below the "Big Dam"	1005 and 1001
Same, at Moose River Rapids	987
Mouth of Namekagon River	912
Mouth of Yellow River	892
Mouth of Clam River	870
Head of Kettle River Rapids (4 miles long, falling 49 feet)	858
Mouth of Kettle River, west of the "Big Island"	824
Foot of Kettle River Rapids	809
Mouth of Snake River	798

	Feet above the sea.
At bridge of the Grantsburg Branch, St. Paul and Duluth Railroad	775
At Rush City ferry	770
Mouth of Sunrise River	758
Mouth of Trade River	753
Head of St. Croix Rapids (6 miles long, falling 55 feet)	742
Mouth of Big Rock Creek	726
Foot of the St. Croix Rapids, at the lower steamboat landing, Taylor's Falls	687
At head of Rock Island	685
At Osceola	683
At bridge of the Minneapolis, Sault Ste. Marie and Atlantic Railway, bed, 670; low and high water	680–697
Mouth of Apple River	672
At bridge of the Wisconsin Central Railroad, bed, 666; ordinary low stage of water, 676; extreme low and high water	670–689
Lake St. Croix (maximum depth, 25 feet), extreme low and high water, 667–687; ordinary stage	672
Junction with the Mississippi River at Prescott	667

NAMEKAGON RIVER.

At railway bridge, 2 miles south of Phipps	1198
At Stinnett	1131
At Superior Junction	1037
Mouth of Totogatic River (before the dam was built on the Namekagon River 1 mile below this point)	918
At road crossing from Grantsburg to the "Big Dam" of the St. Croix River	914
Junction with the St. Croix River	912
Elevations of the Totogatic River, tributary to the Namekagon, are as follows:	
Above and below the upper dam, Sec. 12, T. 42, R. 10	1242–1237
At bridge of the Chicago, St. Paul, Minneapolis and Omaha Railway	1010
White Fish Lake	1030
At foot of dam in Sec. 13, T. 42, R. 13	975

KETTLE RIVER.

At bridge of the Northern Pacific Railroad	1287
At Kettle River Station, St. Paul and Duluth Railroad	1010
At the St. Paul, Minneapolis and Manitoba Railway bridge, near Sandstone, between the Upper and Lower Falls	955
Junction with the St. Croix River, west of the "Big Island"	824

SNAKE RIVER.

At bridge, 1 mile below the mouth of Knife River	958
At bridge of the St. Cloud and Hinckley line of the St. Paul, Minneapolis and Manitoba Railway	945
Mouth of Ann River	943
At the Brunswick Bridge	941
At the old court-house, about a mile east of Brunswick	940
Foot of Millett's Rapids, about 3 miles east of Brunswick	937
Cross and Pokegama Lakes, as flowed by the Chengwatana dam, and the Snake River along the distance of 16 miles from Millett's Rapids	937
Floor of first gateway, from south bank of river, Chengwatana dam.	929
Junction with the St. Croix River	798

CHIPPEWA RIVER AND TRIBUTARIES (WISCONSIN).

[From leveling by United States engineers, under the direction of Maj. C. J. Allen, St. Paul, and from railroad surveys.]

	Feet above the sea.
Crooked Lake	1623
Bowlder Lake	1610
Trout Lake	1593
Dole Lake	1578
Big and Little Manitouish Lakes	1575

	Feet above the sea.
Island Lake	1577
Big Lake	1594
Round Lake	1532
Round Lake dam, top of gate and sill of large sluiceway	1532·7–1528·2
Fence Lake	1563
Crawling Stone, Long, Pokegama, and Flambeau Lakes, each	1562
Rest Lake	1571
Flambeau River at the fork of Manitouish and Bear Creeks	1552
Same, at mouth of Turtle River	1525
Same, above and below Muskalonge Falls	1458–1446
Bridge of Wisconsin Central Railroad, Flambeau	1463·5
Flambeau River here, low water	1445
Bridge of Wisconsin Central Railroad, Glidden	1522·5
Chippewa River here, low and high water	1509–1516
Same, near center of Sec. 28, T. 41, R. 3 W	1442
Bear Lake, enlargement of the Chippewa River	1433
Chippewa River above and below dam, 1 mile west of Bear Lake	1433–1429
Same, head and foot of Cedar Rapids	1420–1404
Same, head and foot of Snap Tail Rapids	1368–1346
On the West Fork of Chippewa River:	
Lost and Cross Lakes	1385
Summer Lake	1396
Partridge Crop Lake	1385
Moose Lake	1362
Water above and below the dam at Moose Lake	1362–1358
West Fork of Chippewa River at mouth of Tea River	1353
Chief Lake	1296
Pokegama Lake	1290
Pa-kwa-wang Lake	1286
Hunter's Lake	1327
Little Chief Lake	1325
On the Courtes Oreilles River:	
Flat Lake	1320
Sand Lake	1301
Fish Lake	1289
Island Lake	1292
Grindstone Lake	1288
Lac Courtes Oreilles	1287
Chippewa River, 1 mile east of Bruce, low and high water	1062–1076
At bridge of the Chicago, St. Paul, Minneapolis and Omaha Railway, Chippewa Falls, low and high water	843–859
At Chippewa Falls, below the ferry landing	792
Head and foot of the Upper Dalles	788–778
Same, of the Lower Dalles	763–756
At bridge of the Chicago, St. Paul, Minneapolis and Omaha Railway, Eau Claire, low and high water	770–792
Mouth of the Eau Claire River, Eau Claire, low water	751
Mouth of Red Cedar River, low and high water	705–728
At Durand, low water	691
At outlet of Dead Lake, low water	684
Junction with the Mississippi River, opposite to Read's Landing, low and high water	663–682

CROW WING RIVER.

Shell Lake, at head of Shell River, estimated	1425
Leaf Lakes, at head of Leaf River, estimated	1340
Leaf River at Bluffton	1305
Crow Wing River at Motley	1208
Junction with the Mississippi River at Crow Wing	1145

LONG PRAIRIE RIVER.

Lakes Miltona and Ida, also Lakes Andrews, Mary, and Lobster, about	1400
(The maximum depth of Lake Miltona is about 80 feet.)	
Long Prairie River above Mill Lake, 3 miles northwest of Alexandria	1349

	Feet above the sea.
Lakes Darling, Carlos, and Le Homme Dieu, about	1330
(The maximum depths of these lakes are respectively about 50, 150, and 75 feet, according to soundings by Rev. C. M. Terry.)	
At Long Prairie	1287
At bridge of the St. Paul and Northern Pacific Railroad	1227
Junction with the Crow Wing River, near Motley	1205
At the head of Fish Trap Brook, tributary to the Long Prairie River:	
Lake Alexandria, about	1275
Fish Trap Lake	1273
(These lakes are probably 150 feet deep, or more, as reported by lumbermen.)	
SAUK RIVER.	
Osakis Lake, about	1310
(The mean depth of this lake is about 25 feet; and its maximum depths in the northeast part, 40–70.—C. M. Terry.)	
Sauk River at Little Sauk	1240
A mile below Sauk Center	1213
Two miles west of Melrose	1201
Two miles east of Melrose	1172
At Richmond	1083
At Cold Spring, above and below the dam	1082–1075
Four miles from its mouth	1035
Junction with the Mississippi, Sauk Rapids	988
CROW RIVER.	
North Fork of Crow River at Lintonville	1207
Same, at bridge of the St. Paul, Minneapolis and Manitoba Railway, 1¼ miles west of Paynesville	1166
Same, at bridge of the Minneapolis and Pacific Railway, Paynesville	1142
Same, at bridge of the Minneapolis and Pacific Railway, 3½ miles east of Paynesville	1118
Lake Koronis, about	1105
On the Middle Fork of Crow River:	
Nest Lake	1162
Green Lake (maximum depth, 40 to 50 feet)	1154
On the South Fork of Crow River:	
Grass Lake, Little and Big Kandiyohi Lakes, and Lake Lillian, about	1125–1110
(The maximum depths of these lakes are 7 to 12 feet.)	
Otter Lake, flowed by the Hutchinson dam, about	1038
At bridge of the branch of the St. Paul, Minneapolis and Manitoba Railway, Huchinson	1026
Mouth of Crane Creek, 2 miles east of Lester Prairie	950
At Mayer	932
Above and below the dam at Watertown	927–920
At Delano	910
Confluence of the North and South Forks of Crow River	901
Crow River at bridge of the Clearwater Branch, St. Paul, Minneapolis and Manitoba Railway, 5 miles from its mouth	855
Junction with the Mississippi River, Dayton	839
CANNON RIVER.	
At railroad bridge near Lake Dora	1040
Lakes Tetonka and Sakata, Waterville, low and high water	996–1002
One mile west of Warsaw	977
Cannon Lake	972
Mouth of Straight River, Faribault, low and high water	956–962
At Northfield, ordinary stage above the dam	902
At bridge of the St. Paul and Kansas City Railway, Randolph	846
At Cannon Falls, pond above the lower dam	783
Four miles above Eagle Mills	732
At Cannon Junction	677
Junction with the Mississippi River, Red Wing	665

ZUMBRO RIVER.

	Feet above the sea.
North Branch at Kenyon	1071
North Middle Branch at bridge of the Chicago, St. Paul and Kansas City Railway	1156
Same, at Pine Island	984
Same, at Oronoco	958
South Middle Branch at bridge of the Chicago, St. Paul and Kansas City Railway	1174
Same, at bridge of the Chicago and Northwestern Railway branch, New Haven	966
South Branch at College Street Bridge, Rochester	983
Zumbro River at Midland Junction	682
Junction with the Mississippi River, near Kellogg	657

ROOT RIVER.

North Branch at High Forest	1213
Junction of North and South Branches, near Lanesboro, about	780
Junction with the Mississippi River, near La Crosse	626

DES MOINES RIVER.

Sources in northwestern Murray County, Minnesota	1800–1900
Lake Shetek, about	1475
Two miles north of the north end of Heron Lake, about	1375
Heron Lake	1406
At Windom	1334
Two miles northwest of Jackson	1300
The following lakes, though near the Des Moines River, are tributary to the Little Sioux and Missouri Rivers:	
Spirit Lake	1395
Okoboji Lakes	1390
At Estherville	1254
At Emmetsburg, about	1190
Mouth of the East Fork	1047
At Fort Dodge	1000
At Moingona	870
At Des Moines	776
At Eddyville	698
Junction with the Mississippi River, near Keokuk	476

MINNESOTA RIVER SYSTEM.

[From leveling by United States engineers, under the direction of Gen. G. K. Warren and Maj. C. J. Allen, and from railway surveys.]

MINNESOTA RIVER.

[The elevations refer, unless otherwise noted, to the stage of ordinary low water.]

	Feet above the sea.
At Brown's Valley	972·5
Big Stone Lake (maximum depths, 15 to 30 feet), low and high water	962–967
Mouth of Pomme de Terre River	935
Lac Qui Parle (maximum depth, 12 feet)	926
Mouth of Chippewa River, Montevideo	913
Above Granite Falls	908
Below Granite Falls, low and high water	870–880
Below Minnesota Falls	856
Mouth of Yellow Medicine River	848
Below Patterson's Rapids, at the east side of Swede's Forest	825
Mouth of Redwood River	818
At Morton, low and high water	814–836
At Fort Ridgely	793
At New Ulm	784
Mouth of the Big Cottonwood River, low and high water	782–807
At Judson	760
Mouth of the Blue Earth River	756

	Feet above the sea.
At Mankato, low and high water	752–778
At the line of Blue Earth and Le Sueur Counties, about	743
At the Winona and St. Peter (Chicago and Northwestern) Railway bridge, low and high water	733–755
At East St. Peter	730
At Traverse des Sioux	726
At Ottawa	723
At Le Sueur, low and high water	717–742
At East Henderson, low and high water	711–738
At Henderson, low and high water	710–737
At Blakely and Faxon, low and high water	700–726
At Belle Plaine, low and high water	695–722
Crest of Little Rapids, low and high water	692–718
Foot of same, low and high water	690–718
At Hamilton, low and high water	689–715
Junction with the Mississippi River at Fort Snelling, low and high water	688–710
(The last 30 miles of this river, from Little Rapids to its mouth, are held, at its lowest stage, as almost level backwater by the recent alluvial deposits of the Mississippi. Because of this dam across the mouth of the Minnesota River, its depth at low water along this extent of 30 miles is from 10 to 25 feet, quite uniformly averaging, except at the mouths of tributaries, about 20 feet.)	
POMME DE TERRE RIVER.	
At Parkdale	1226
Lake Christina and Pelican Lake, about	1215
At bridge of the St. Paul, Minneapolis and Manitoba Railway line, from Evansville to Tintah, 1 mile south of Pomme de Terre Lake	1160
At bridge of the Minneapolis and Pacific Railway	1147
One and one-half miles east of Morris, bed	1074
Three miles farther south	1068
At railway bridge 2 miles northeast of Appleton	1005
At Appleton (St. Paul, Minneapolis and Manitoba Railway bridge)	983
Same (Chicago, Milwaukee and St. Paul Railway bridge)	978
Junction with the Minnesota River	935
CHIPPEWA RIVER (MINNESOTA).	
Two miles southeast of Evansville	1339
At bridge of the Minneapolis and Pacific Railway	1184
At Cyrus	1110
Lake Reno (20 feet deep), about	1400
Lake Whipple (maximum depth, 85 feet), low and high water	1133–1137
Lake Emily, about	1080
Lakes Villard and Amelia	1347
East Branch of the Chippewa River, at bridge of the Minneapolis and Pacific Railway	1307
Lake Johanna, about	1200
Mouth of the East Branch, about	1025
At Benson	1022
Junction with the Minnesota River, Montevideo	913
LAC QUI PARLE RIVER.	
West Branch, at Dawson	1029
Confluence of the West and East Branches, about	1025
Lake Hendricks, tributary at its highest stage to the East Branch, about	1750
Junction with the Minnesota River	925
YELLOW MEDICINE RIVER.	
Lake Shaokatan, tributary at its highest stage to this river, about	1750
Yellow Medicine River, at Hanley Falls	1017
Junction with the Minnesota River	848
REDWOOD RIVER.	
Lake Benton	1754
At Marshall, about	1155

	Feet above the sea.
Head of series of falls at Redwood Falls	953
Foot of same, about	856
At bridge of the Minneapolis and St. Louis Railway	831
Junction with the Minnesota River	818
COTTONWOOD RIVER.	
Sources near Balaton, about	1500
At line between Lyon and Redwood Counties, about	1120
At line between Redwood and Brown Counties, about	1030
At Iberia, about	900
Junction with the Minnesota River	782
BLUE EARTH RIVER.	
Union Slough, Iowa, at head of the most southern branch of the Blue Earth River, formerly the channel of a river flowing to the East Fork of the Des Moines from the glacial Lake Minnesota in the Blue Earth and Minnesota Basins, about	1150
At Blue Earth City	1049
Two miles southwest of Winnebago City	1022
At Vernon Center and Edgewood	941
Junction with the Minnesota River near Mankato	756
LE SUEUR RIVER.	
In Sec. 32, Otisco, Le Sueur County	1117
Lake Elysian, about	1040
At line between Waseca and Blue Earth Counties, about	1010
At railroad bridge, 1 mile south from the junction of the Le Sueur with the Blue Earth River	780

MISSOURI RIVER SYSTEM.

[From the Missouri River Commission, and from railroad surveys.]

MISSOURI RIVER.

[From leveling and gauge records of the Missouri River Commission in report on Stages of the Missouri River from St. Charles, Mo., to Fort Pierre, Dak., 1886 (therein referred to the St. Louis directrix), and from railroad surveys.]

	Feet above the sea.
Junction of the Jefferson, Madison, and Gallatin Rivers, forming the Missouri River, at Gallatin, Mont., very nearly	4000
At Townsend, Mont., low water	3793
Mouth of Sunrise River, low and high water	3299–3306
At Great Falls, St. Paul, Minneapolis and Manitoba Railway bridge, head of succession of falls extending 18 miles, reported to amount in total to 512 feet, low and high water	3295–3302
Mouth of Portage River (Highwood Creek), foot of this series of falls and of portage 18 miles long	2783
At Fort Benton, ordinary low water, about	2565
Mouth of Marias River, low and high water, about	2545–2560
Mouth of Milk River, low and high water, about	2020–2040
Mouth of Poplar River, low and high water	1935–1952
Mouth of the Yellowstone River, at Fort Buford, low and high water, about	1855–1875
At Williston, 1 mile above the mouth of Little Muddy Creek (North Dakota), low and high water	1825–1848
Mouth of the Little Missouri River, about	1740
At Bismarck, N. Dak., low water, 1,618; ordinary high water, 1,633; extreme high water, Mar. 31, 1881, and Mar. 19–24, 1887, 1,646	1618–1646
Mouth of the Cheyenne River, about	1460
At Fort Pierre, S. Dak. (gauge at mouth of Bad River), low water [about 1 foot above extreme low water], Nov. 29, 1882	1413·80
[At Pierre (opposite to Fort Pierre), extreme low and high water, according to the survey of the Chicago and Northwestern Railway	1426–1445]
At Chamberlain, S. Dak., low water, Nov. 30, 1882, 1,324·30; extreme low water	1323
At Bijou Hills, S. Dak., low water, Nov. 30, 1882	1281·10

	Feet above the sea.
At Fort Randall, S. Dak., low water, Nov. 26, 1881, 1,236·30; Dec. 2, 1882	1235·90
Mouth of the Niobrara River, extreme low water, about	1205
At Running Water, S. Dak., low water, Nov. 18–30, 1881, 1,203·50; extreme low water, about	1202·50
At Yankton, S. Dak., low water, Nov. 24, 1881	1160·76
From notes furnished by E. D. Palmer, city engineer, and from railway profiles, the following elevations in Yankton are obtained:	
Chicago and Northwestern depot	1206
Chicago, Milwaukee and St. Paul depot	1196
Missouri River, extreme low water, about 1,157; extreme high water, April, 1881, 1,198	1157–1198
(This maximum range of 41 feet, considerably exceeding that of other portions of the river above and below Yankton, is caused by the accumulation of gorged ice during the spring flood at the bend 8 miles farther east, just below the mouth of the James River. Mr. Palmer states that the ice of the Missouri seldom or never breaks up in spring without becoming gorged at that sharp bend, raising the flood at Yankton above its normal height.)	
Mouth of the James or Dakota River, extreme low and high water, about	1150–1195
At Vermilion, S. Dak., low water, Nov. 22, 1880, 1,131.00; high water, Mar. 26, 1881, 1,143·60	1131–1143·60
(Because of a cut-off made by the Missouri River during the unusually high flood of the spring of 1881, this station was left about 3 miles from its present channel, the mouth of the Vermilion River being thus changed from Vermilion to near Butler's Landing.)	
At Butler's Landing, about 5 miles south of Vermilion, S. Dak., low water, Dec. 24, 1881, 1,125·60; high water, Apr. 27, 1881, 1,136·00	1125·60–1136
Mouth of the Big Sioux River, extreme low and high water, about.	1080–1102
At Sioux City, Iowa, extreme low and high water, 1879 to 1885 (range, 22·50 feet)	1076·50–1099
The lowest and highest stages of the river here during the years 1879 to 1885 were as follows:	
1879, l. w., Dec. 5, 1078·30; h. w., Apr. 7, 1092.	
1880, l. w., Jan. 1, 15, and 26, 1079·40; h. w., July 7 and 19, 1090·50.	
1881, l. w., Dec. 6, 1077·50; h. w., Apr. 23, 1099.	
1882, l. w., Dec. 4, 1076·50; h. w., June 27, 1089·90.	
1883, l. w., Dec. 6, 1076·80; h. w.. July 9, 1090.	
1884, l. w., Jan. 1, 1078·10; h. w., Apr. 4, 1092·40.	
1885, l. w., Dec. 16, 1081·51; h. w., June 15, 1091·68.	
At Decatur, Nebr., range, 18·50 feet; low water, Nov. 20–26, 1881, 1032·70; high water, Apr. 25, 1881, 1051·20	1032·70–1051·20
At Blair, Nebr. (gauge at old transfer landing), range, 20·70 feet; low water, Nov. 23, 1880, 986·10; high water, Apr. 24, 1881, 1006·80	986·10–1006·80
At Omaha, Nebr., extreme low and high water, 1873 to 1885 (range, 22·10 feet)	960·30–982·40
The lowest and highest stages of the river here during the years 1873 to 1885 were as follows:	
1873, l. w., Dec. 2, 960·30; h. w., July 4, 974·80.	
1874, l. w., Nov. 21, 960·90; h. w., June 15–18, 971·40.	
1875, l. w., Nov. 1, 960·60; h. w., Apr. 28, 976·60.	
1876, l. w., Nov. 20, 960·60; h. w., June 21, 973·60.	
1877, l. w., Dec. 20, 962·70; h. w., June 13, 975·90.	
1878, l. w., Jan. 4, 963·50; h. w., June 25, 976·40.	
1879, l. w., Nov. 30, 963·10; h. w., June 28, 975·80.	
1880, l. w., Jan. 27, 962·70; h. w., July 1, 975·10.	
1881, l. w., Nov. 25, 962·60; h. w., Apr. 24, 982·40.	
1882, l. w., Dec. 6, 961·40; h. w., June 28, 973·20.	
1883, l. w., Dec. 20, 961·50; h. w., July 11, 972·80.	
1884, l. w., Dec. 15, 962·80; h. w., Apr. 6, 975·60.	
1885, l. w., Dec. 8, 961·63; h. w., June 17, 974·06.	
Mouth of the Platte River, extreme low and high water, about	941–961
At Plattsmouth, Nebr., extreme low and high water, 1873 to 1885 (range, 20·50 feet)	939·60–960·10

Feet above the sea.

The lowest and highest stages of the river here during the years 1873 to 1885 were as follows:
1873, l. w., Dec. 6, 940·80; h. w., July 3, 957·30.
1874, l. w., Nov. 25 and Dec. 19, 940·10; h. w., June 16, 953.
1875, l. w., Nov. 22, 940·10; h. w., Apr. 28, 954·10.
1876, l. w., Feb. 1 and Mar. 2, 940·60; h. w., June 21 and July 4, 952·80.
1877, l. w., Mar. 9, 940·20; h. w., June 13, 954·70.
1878, l. w., Jan. 8, 940·10; h. w., June 25, 954·90.
1879, l. w., Dec. 9 and 12, 941·20; h. w., June 27, 953·20.
1880, l. w., Mar. 15, 939·60; h. w., July 8, 953·90.
1881, l. w., Nov. 25, 943·30; h. w., Apr. 25, 960·10.
1882, l. w., Feb. 22, 940·60; h. w., June 29, 953·90.
1883, l. w., Dec. 25, 940·10; h. w., June 28, 954·60.
1884, l. w., Dec. 20, 942·50; h. w., Apr. 6, 954·60.
1885, l. w., Dec. 9, 941·86; h. w., June 17, 955·06.

At Nebraska City, Nebr., extreme low and high water, 1879 to 1885 (range, 14·60 feet) ..... 907·50–922·10

The lowest and highest stages of the river here during the years 1879 to 1885 were as follows:
1879, l. w., Dec. 11, 907·70; h. w., June 28, 919·70.
1880, l. w., Jan. 29 and Mar. 1, 908·90; h. w., July 9, 918·10.
1881, l. w., Dec. 17, 909·60; h. w., Apr. 27, 922·10.
1882, l. w., Jan. 4, 907·50; h. w., June 30, 918·30.
1883, l. w., Dec. 1, 908·70; h. w., June 28, 919·70.
1884, l. w., Dec. 16, 908; h. w., Apr. 7, 920·80.
1885, l. w., Dec. 10, 907·86; h. w., June 17, 920·06.

At Brownsville, Nebr., extreme low and high water, 1881 to 1885 (range, 19·50 feet) ..... 875·10–894·60

The lowest and highest stages of the river here during the years 1881 to 1885 were as follows:
1881, l. w., Nov. 25, 878·70; h. w., Apr. 26, 894·60.
1882, l. w., Dec. 9, 875·10; h. w., June 30, 890·40.
1883, l. w., Dec. 29, 877·60; h. w., June 24, 891·10.
1884, l. w., Dec. 18, 877; h. w., Apr. 8, 891·60.
1885, l. w., Dec. 8, 879·03; h. w., June 17, 890·23.

At White Cloud, Kans., extreme low and high water, 1881 to 1885 (range, 22·81 feet) ..... 828·70–851·51

The lowest and highest stages of the river here during the years 1881 to 1885 were as follows:
1881, l. w., Dec. 31, 832·70; h. w., Apr. 28, 851·51.
1882, l. w., Dec. 6, 832; h. w., July 1, 847·40.
1883, l. w., Dec. 21, 831·20; h. w., June 24, 849·60.
1884, l. w., Dec. 18, 828·70; h. w., June 23, 848·70.
1885, l. w., Dec. 10, 830·18; h. w., June 17, 848·26.

At St. Joseph, Mo., extreme low and high water, 1872 to 1885 (range, 26 feet) 790–816

The lowest and highest stages of the river here during the years 1872 to 1885 were as follows:
1872, l. w., Nov. 29, 790·20; h. w., June 26–29 and July 3, 804·70.
1873, l. w., Dec. 9–12, 790; h. w., July 5, 809.
1874, l. w., Jan. 6, 791·20; h. w., June 17, 805·80.
1875, l. w., Jan. 2, 792; h. w., Apr. 29, 808·50.
1876, l. w., Feb. 6, 792·70; h. w., July 5, 807·60.
1877, l. w., Dec. 1, 795·40; h. w., June 14, 809·90.
1878, l. w., Dec. 22, 793·70; h. w., July 2, 810·60.
1879, l. w., Dec. 17, 791.50; h. w., June 30, 808·60.
1880, l. w., Nov. 28, 793·30; h. w., July 10, 807·90.
1881, l. w., Nov. 23 and Dec. 31, 796; h. w., Apr. 29, 816.
1882, l. w., Dec. 13, 790·20; h. w., June 30 and July 2, 809.
1883, l. w., Dec. 26, 791·20; h. w., June 26, 811·60.
1884, l. w., Jan. 1, 791·80; h. w., Apr. 7, 808·30.
1885, l. w., Dec. 23, 794·86; h. w., June 18, 808.

At Atchison, Kans., extreme low and high water, 1879 to 1885 (range, 24·20 feet) ..... 765–789·20

The lowest and highest stages of the river here during the years 1879 to 1885 were as follows:
1879, l. w., Feb. 11, 769·10; h. w., June 30, 782·50.

	Feet above the sea.
1880, l. w., Nov. 27, 765·80; h. w., July 10, 781·90.	
1881, l. w., Nov. 26, 767·80; h. w., Apr. 29, 789·20.	
1882, l. w., Dec. 9–12, 765·60; h. w., July 2, 781·80.	
1883, l. w., Dec. 30, 765; h. w., June 26, 784·10.	
1884, l. w., Jan. 1, 765·30; h. w., Apr. 9, 782.	
1885, l. w., Dec. 24, 767·36; h. w., June 18, 782·01.	
At Fort Leavenworth, Kans., extreme low and high water, 1872 to 1881 (range, 26·20 feet)	743·28–769·48
The lowest and highest recorded stages of the river here during the years 1872 to 1881 were as follows:	
1872, l. w., Dec. 4, 744·12; h. w., July 14, 759·12.	
1873, l. w., Dec. 10, 744·53; h. w., July 5, 761·80.	
1874, l. w., Jan. 6, 744·36; h. w., June 19, 758·63.	
1875, l. w., Jan. 1, 744·73; h. w., Apr. 30, 760·43.	
1876, l. w., Dec. 6, 744·78; h. w., July 6, 759·43.	
1877, l. w., Dec. 2, 746·43; h. w., June 13, 761·93.	
(The low water of Dec. 18, 1877, was not recorded.)	
1878, l. w., Jan. 10, 745·13; h. w., July 2, 761·68.	
1879, l. w., Dec. 18, 745·48; h. w., June 30, 759·53.	
1880, l. w., Nov. 26, 743·28; h. w., July 11, 759·23.	
(The record at Leavenworth does not note the stage of unusually low water Nov. 26, 1880.)	
1881, l. w., Feb. 5, 748·43; h. w., Apr. 29, 769·48.	
At Leavenworth, Kans., extreme low and high water, 1873 to 1885 (range, 23·80 feet)	741·80–765·60
The lowest and highest recorded stages of the river here during the years 1873 to 1885 were as follows:	
1873, l. w., Dec. 9, 741·80; h. w., July 5, 759·60.	
1874, l. w., Jan. 6, 741·80; h. w., June 17, 756·30.	
1875, l. w., Jan. 1, 743; h. w., Apr. 29, 757·80.	
1876, l. w., Jan 26 and 30, 744·80; h. w., July 6, 757·30.	
(The low water of Dec. 6, 1876, was not recorded.)	
1877, l. w., Dec. 18, 744·70; h. w., June 13, 760·50.	
1878, l. w., Jan. 10, 744·40; h. w., July 2, 759·30.	
1879, l. w., Mar. 1, 744·20; h. w., June 27 and 30, 757·20.	
(The low water of Dec. 18, 1879, was not recorded.)	
1880, l. w., Feb. 3 and 8, 743·60; h. w., July 15, 756·80.	
1881, l. w., Jan. 1, 745·80; h. w., Apr. 29, 765·60.	
1882, l. w., Dec. 15, 742·20; h. w., July 2, 758·90.	
1883, l. w., Dec. 26, 743·30; h. w., June 26, 762·30.	
1884, l. w., Dec. 29, 745·40; h. w., June 24, 758·70.	
1885, l. w., Dec. 10, 744·86; h. w., June 19, 759·24.	
Mouth of the Kansas River, extreme low and high water, about	718–745
At Kansas City, Mo., extreme low and high water, 1873 to 1885 (range, 27·55 feet)	716·18–743·73
[Same, high water, 1844 (36 feet above extreme low water), 752, according to Gannett's Dictionary of Altitudes.]	
The lowest and highest stages of the river here during the years 1873 to 1885 were as follows:	
1873, l. w., Dec. 30, 719·20; h. w., June 25 and July 5, 735·70.	
1874, l. w., Jan. 6, 716·70; h. w., June 18, 732·60.	
1875, l. w., Jan. 2, 718·45; h. w., Apr. 30, 734·28.	
1876, l. w., Dec. 9, 718·77; h. w., Apr. 17 and June 14, 733·87.	
1877, l. w., Dec. 17, 720·56; h. w., June 10, 738·62.	
1878, l. w., Jan. 12, 720·24; h. w., July 2, 736·24.	
1879, l. w., Feb. 28, 719·51; h. w., June 30, 735·43.	
1880, l. w., Nov. 25, 718·03; h. w., July 12–15, 733·03.	
1881, l. w., Feb. 21, 720·78; h. w., Apr. 30, 743·73.	
1882, l. w., Feb. 24, 717·63; h. w., July 3, 736·38.	
1883, l. w., Dec. 31, 717·01; h. w., June 26, 740·46.	
1884, l. w., Jan. 1, 716·18; h. w., June 24, 735·31.	
1885, l. w., Dec. 9, 718·66; h. w., June 19, 735·60.	
At Missouri City, Mo., low water, Dec. 25, 1878, 694·80; high water, June 30, 1879, 712·85	694·80–712·85
At Camden, Mo., low water, Dec. 21–24, 1878, 678·50; high water, June 30, 1879, 693·50	678·50–693·50
At Lexington, Mo., extreme low and high water, 1873 to 1885 (range, 25·20 feet)	664·10–689·30

Feet above the sea.

The lowest and highest stages of the river here during the years 1873 to 1885 were as follows:
1873, l. w., Nov. 19–22, 668·60; h. w., July 7, 682·20.
1874, l. w., Dec. 31, 666·60; h. w., June 19, 679·20.
1875, l. w., January, 666·30; h. w., May 1, 680·80.
1876, l. w., Jan. 17 and Feb. 2–7, also Dec. 6–12 and 26–31, 667·30; h. w., June 16, 681.10.
1877, l. w., Jan. 1–28, 667·30; h. w., June 11, 684·60.
1878, l. w., Dec. 28, 668·90; h. w., July 4, 683·70.
1879, l. w., Dec. 20, 667·60; h. w., June 30, 682·70.
1880, l. w., Dec. 30, 666·70; h. w., Apr. 9, 679·20.
1881, l. w., Feb. 4, 667; h. w., May 1, 689·30.
1882, l. w., Dec. 12, 664·10; h. w., July 3, 680·90.
1883, l. w., Jan. 3, 664·70; h. w., June 27, 685·80.
1884, l. w., Jan. 2, 665·60; h. w., Apr. 10, 680·90.
1885, l. w., Dec. 18, 665·03; h. w., Mar. 8, 685·91.

At Waverly, Mo., low and high water, 1878 and 1883 to 1885 (range, 24·06 feet) ..... 645–669·06

Recorded stages of low and high water here were as follows:
1878, l. w., Dec. 21, 645; 1879, h. w., June 30, 660·70.
1883, l. w., Jan. 3, 645·31; h. w., June 27, 665·11.
1884, l. w., Dec. 25, 647·51; h. w., June 25, 661·71.
1885, l. w., Dec. 17, 646·41; h. w., Mar. 13, 669·06.

At Miami, Mo., low water, Feb. 11, 1879, 622·41; high water, June 28 and July 1, 1879, 640·21 ..... 622·41–640·21

At De Witt, Mo., low and high water, 1883 to 1885 (range, 23·20 feet) ..... 613·61–636·81

The lowest and highest stages of the river here during the years 1883 to 1885 were as follows:
1883, l. w., Jan. 6 and Dec. 31, 616·41; h. w., June 27, 636·81.
1884, l. w., Dec. 20, 613·61; h. w., Apr. 10, 632·41.
1885, l. w., Dec. 15, 616·31; h. w., June 20, 633·13.

At New Frankfort, Mo., low water, Mar. 3, 1879, 602·48; high water, July 1, 1879, 615·53 ..... 602·48–615·53

At Glasgow, Mo., extreme low and high water, 1879 to 1885 (range, 24·91 feet) ..... 590·56–615·47

The lowest and highest stages of the river here during the years 1879 to 1885 were as follows:
1879, l. w., Dec. 20, 590·56; h. w., July 1, 607·72.
1880, l. w., Mar. 21, 591·16; h. w., July 13, 604·68.
1881, l. w., Jan. 2, 591·43; h. w., May 3, 614·08.
1882, l. w., Dec. 30, 592·51; h. w., July 2, 611·43.
1883, l. w., Dec. 31, 591·33; h. w., June 23, 615·47.
1884, l. w., Jan. 1, 591·12; h. w., Apr. 10, 607·40.
1885, l. w., Dec. 15, 591·89; h. w., June 22, 609·08.

At Boonville, Mo., extreme low and high water, 1874 to 1885 (range, 23·22 feet) ..... 564·90–588·12

Same, high water, 1844 ..... 597·50

The lowest and highest stages of the river here during the years 1874 to 1885 were as follows:
1874, l. w., Dec. 31, 564·90; h. w., June 19, 577·31.
1875, l. w., Jan. 1, 564·90; h. w., July 8, 584·86.
1876, l. w., Feb. 7, 567·53; h. w., May 8, 583·20.
1877, l. w., Jan. 1, 569·61; h. w., June 13, 585·20.
1878, l. w., Dec. 24, 567·50; h. w., July 6, 582·45.
1879, l. w., Feb. 17, 568·20; h. w., July 1, 583·20.
1880, l. w., Dec. 11, 567·95; h. w., July 13, 580·45.
1881, l. w., Jan. and Feb., 570·29; h. w., May 3, 588·12.
1882, l. w., Dec. 18, 566·11; h. w., July 2, 585·69.
1883, l. w., Jan. 7, 566·53; h. w., June 23, 588·10.
1884, l. w., Jan. 9, 569·49; h. w., Apr. 10, 580·59
1885, l. w., Dec. 18, 568·41; h. w., June 22, 583·41.

At Providence, Mo., low water, Dec. 28, 1878, 545·21; high water, July 1, 1879, 561·31 ..... 545·21–561·31

At Jefferson City and Cedar City, Mo., extreme low and high water, 1878 to 1885 (range, 22·66 feet) ..... 523·19–545·85

[Same, high water, July, 1844 (30·83 feet above extreme low water), 554·02, according to Proceedings of the Academy of Science, St. Louis, Transactions, vol. 4, p. xvii.]

	Feet above the sea.
Recorded stages of low and high water here from 1878 to 1885 were as follows:	
1878, l. w., Dec. 20, 523·19.	
1879, l. w., Jan. 11 and Mar. 3, 524·23; h. w., June 28, 538·27.	
1880, l. w., Dec. 31, 524·18.	
1881, l. w., Jan. 1, 524·68; h. w., May 4, 545·85.	
1882, l. w., Dec. 19, 524·72; h. w., July 2, 543·70.	
1883, l. w., Jan. 11, 523·80; h. w., June 23, 545·73.	
1884, l. w., Jan. 3, 523·28; h. w., July 16, 538·91.	
1885, l. w., Dec. 15, 524·36; h. w., June 21, 540·46.	
At Fisher's Landing, Mo., low water, Dec. 23, 1878, 502·18; high water, July 2, 1879, 517·23	502.18–517·23
At Hermann, Mo., extreme low and high water, 1873 to 1885 (range, 25·33 feet)	479·92–505·25
The lowest and highest stages of the river here during the years 1873 to 1885 were as follows:	
1873, l. w., Dec. 31, 484; h. w., June 10, 496·67.	
1874, l. w., Jan. 21, 482·92; h. w., June 19, 497·34.	
1875, l. w., Jan. 5, 483·25; h. w., Aug. 1, 502·75.	
1876, l. w., Dec. 9, 484; h. w., July 6, 503·67.	
1877, l. w., Oct. 13, 487·17; h. w., June 13, 503·25.	
1878, l. w., Dec. 21, 479·92; h. w., July 5, 499·25.	
1879, l. w., Dec. 22, 484·09; h. w., June 29, 500·25.	
1880, l. w., Dec. 6, 484·09; h. w., July 15, 497·50.	
1881, l. w., Jan. 28, 486·09; h. w., May 4, 504·50.	
1882, l. w., Dec. 17, 481·42; h. w., July 3, 503·01.	
1883, l. w., Jan. 9, 482·25; h. w., June 24, 505·25.	
1884, l. w., Jan. 4, 484·59; h. w., May 6, 498·92.	
1885, l. w., Jan. 28, 486·71; h. w., June 16, 503·01.	
At Washington, Mo., low water, Feb. 21, 1879, 458·01; high water, July 2, 1879, 474·08	458·01–474·08
At Cottleville Landing, Mo., low water, Dec. 27, 1878, 437·02; high water, July 3, 1879, 451·86	437·02–451·86
At St. Charles, Mo., extreme low and high water, 1879 to 1885 (range, 26·82 feet)	416·16–442·98
The lowest and highest stages of the river here during the years 1879 to 1885 were as follows:	
(1878, l. w., Dec. 25, 416·73.)	
1879, l. w., Dec. 26, 416·16; h. w., July 3, 436·35.	
1880, l. w., Dec. 12, 416·28; h. w., July 14, 432·95.	
1881, l. w., Jan. 1, 418·73; h. w., May 5, 441·39.	
1882, l. w., Dec. 19, 416·36; h. w., July 4, 438·74.	
1883, l. w., Jan. 10, 416·36; h. w., June 24, 442·98.	
1884, l. w., Jan. 4, 416·66; h. w., July 17, 434·41.	
1885, l. w., Dec. 18, 417·71; h. w., June 22, 437·28.	
At Jamestown Landing, Mo., about 6 miles above the mouth of the river, low water, Dec. 24, 1878, 403·43; high water, July 3, 1879, 418·14	403·43–418·14
Junction with the Mississippi River, extreme low and high water, approximately	395–435
(St. Louis directrix, 412·71 feet above mean tide in the Gulf of Mexico at Biloxi, Miss.)	

MILK RIVER.

[At bridges of the St. Paul, Minneapolis and Manitoba Railway, low water.]

Three and 3¼ miles west of Yantic, about	2425
Two miles east of Yantic	2406
At Malta, low and high water	2220–2239
Two miles west of Glasgow, about	2055
Junction with the Missouri River, low and high water, about	2020–2040

CHEYENNE RIVER.

South Fork at bridge of the Fremont, Elkhorn and Missouri Valley Railroad, Black Hills Branch	2918
Junction of the North and South Forks (according to Newton and Jenney)	2470
Junction with the Missouri River, about	1460

JAMES OR DAKOTA RIVER.

	Feet above the sea.
At New Rockford	1502
Arrow Wood Lake, about	1440
Jim Lake, about	1435
At Jamestown	1382
At Montpelier	1334
At Grand Rapids	1298
At La Moure	1289
Lake Columbia, nearly 30 miles long (also called Sand Lake; the Chedi and Tchan-chicahah Lakes of Nicollet)	1286
At foot of the Columbia dam	1276
At bridge of Aberdeen Branch, St. Paul, Minneapolis and Manitoba Railway	1272
Three miles east of Bath	1269
At Frankfort	1240
At Huron, low and high water	1227–1245
At Forestburg	1213
Mouth of Firesteel Creek, 3 miles east of Mitchell	1206
At James River Station	1178
At bridge of the Chicago, Milwaukee and St. Paul Railway, 4 miles northeast of Yankton	1161
Junction with the Missouri River, extreme low and high water, about	1150–1195

VERMILION RIVER.

West Fork of Vermilion River at Howard	1536
Same, 1½ miles west of Salem	1460
Same, 1½ miles west of Parker	1328
East Fork of Vermilion River, near Winfred	1625
Same, at Montrose	1458
Junction of the West and East Forks, about	1290
At railroad bridge near Vermilion	1129
Junction with the Missouri River	1125

BIG SIOUX RIVER.

Lake Kampeska	1714
At Watertown	1709
At Volga	1596
At Flandrean, above and below the dam	1523–1514
Two miles southwest of Flandrean	1510
One mile south of Sioux Falls Junction	1497
Six miles south of Sioux Falls Junction	1479
At Dell Rapids railroad bridge	1470
Two miles west of Sioux Falls	1406
Sioux Falls, low and high water at head of the falls	1383–1388
Same, low water at foot of the falls	1307
At Brandon, low and high water	1284–1305
Three miles east of Canton	1228
Mouth of Rock River, about	1170
At Hawarden	1147
At railway bridge between Westfield and Elk Point	1098
Junction with the Missouri River, near Sioux City, low and high water, about	1080–1102

ROCK RIVER.

Four miles west of Woodstock	1648
Three miles northwest of Edgerton	1567
At Luverne (below the mill)	1428
At bridge of Burlington, Cedar Rapids and Northern Railway, Rock Rapids	1320
Four and a half miles south of Rock Rapids, low and high water	1299–1314
One mile south of Doon, low and high water	1251–1269
Junction with the Big Sioux River, about	1170

STREAMS AND LAKES ON THE CANOE ROUTE FROM LAKE SUPERIOR TO THE LAKE OF THE WOODS, BY WAY OF THE KAMINISTIQUIA, DOG, STURGEON, AND RAINY RIVERS.

[Determined by leveling by S. J. Dawson in 1857 and 1858, and published in Hind's Narrative of the Canadian Exploring Expeditions, London, 1860, vol. ii, pp. 399-402; corrected approximately by comparison with the survey of the Canadian Pacific Railway.]

	From Lake Superior.	Above the sea.
	Miles.	*Feet.*
Mouth of the Kaministiquia River, Lake Superior	0·0	602
Mountain portage (Kakabeka Falls), Kaministiquia River, 248 rods, ascending 119 feet (including 14 feet of rapids below the falls)	29·2– 30·0	681–800
Rocky portage (or Ecarté portage), 148 rods, ascending 63 feet	30·2– 30·7	800–863
(Nine portages, successively 6½, 12½, 7, 19, 10, 3, 3, 3, and 15 feet, intervene between the last and Little Dog Lake.)		
Little Dog Lake, 1·2 miles across on this route	52·3– 53·5	1002
Great Dog portage, 1¾ miles, ascending 348 feet to Great Dog Lake	53·5– 55·2	1002–1350
Summit of this portage (a broad and massive sand ridge)	54·0	1470
Highest part of this sand ridge, east of the portage path, about	54·0	1500
("The Great Falls of Little Dog River are surprisingly beautiful. The difference in level between Little and Great Dog Lake . . . is descended by the foaming torrent in six successive leaps.")		
Great Dog Lake, 90 feet deep, crossed 10¾ miles on this route, to the mouth of Dog River	55·2– 66·0	1350
Mouth of Prairie River, tributary to Dog River	98·8	1378
Cold Water Lake, crossed 0·2 mile on this route	101·9–102·1	1381
Prairie portage, 2½ miles, ascending 157 feet, to Height of Land Lake	102·1–104·6	1381–1538
Summit of this portage, about	.....	1570
The highest land there within view is about	.....	1600
Height of Land Lake, crossed 0·2 mile on this route	104·6–104·8	1538
(The portage from this to Savanne Lake "passes over a low sandy ridge supporting small pine.")		
Savanne Lake, crossed 1½ miles on the route	105·4–106·9	1522
Great Savanne portage, 1½ miles, descending 32 feet to the Savanne River	106·9–108·4	1522–1490
Thousand Lakes [Lac des Mille Lacs], 21¼ miles on the route	121·6–143·4	1485
Same, low and high water, approximately	.....	1483–1488
(The Seiné River, outflowing from this lake to Rainy Lake, has a total descent of 368 feet, approximately. Hind states that it "falls 350 feet by 29 steps varying in altitude from 3 to 36 feet.")		
Baril Lake, on the head stream of Sturgeon River, crossed 8 miles on the route	143·6–151·6	1487
Brulé portage, 84 rods, descending 47 feet	151·6–151·9	1487–1440
Upper Brulé Lake (or Cannibals' Lake), 8 miles on the route	151·9–159·9	1440
Lower Brulé Lake, 4½ miles on the route	159·9–164·1	1437
Great French portage, 1¾ miles, descending 100 feet to French Portage Lake	164·1–165·8	1437–1337
French Portage Lake, 1½ miles on the route	165·9–167·4	1337
Pickerel Lake, 13 miles on the route	169·9–182·9	1336
Pickerel portage, 104 rods, descending 7 feet to Doré Lake	182·9–183·2	1336–1329
Doré Lake, 1¾ miles on the route	183·2–185·0	1329
Deux Rivières portage, 128 rods, descending 117 feet to Sturgeon Lake	185·0–185·4	1329–1212
Sturgeon Lake, 23½ miles on the route	185·4–208·6	1212
First Sturgeon Rapids, descending 4 feet in 44 rods	208·6–208·7	1212–1208
Second Sturgeon Rapids, portage 12 rods, descending 6 feet	209·0	1208–1202

STREAMS AND LAKES ON THE CANOE ROUTE, ETC.—Continued.

	From Lake Superior.	Above the sea.
	Miles.	*Feet.*
Island portage, 12 rods, descending 10 feet	221·2	1197–1187
Nequaunquon Lake (or Lac la Croix), 8 miles on the route	225–233	1186
Rattlesnake portage, Namekan River, 20 rods, descending 12 feet	235·2–235·3	1184–1172
Crow portage, 32 rods, descending 10 feet	238·6–238·7	1171–1161
Grand Falls portage, 24 rods, descending 16 feet	245·2–245·3	1158–1142
Foot of Grand Rapids, Namekan River	248·8	1127
Lake Namekan, 6½ miles on this route	251·3–257·8	1126
Rainy Lake, 38 miles on this route	263·3–301·3	1117
Same, low and high water, approximately	.....	1115–1120
Rapids, Rainy River, ½ mile, descending 3 feet	301·3–301·8	1117–1114
Chaudière Falls, close east of Fort Francis, portage 32 rods, descending 23 feet	303·3–303·4	1114–1091
Manitou Rapids, descending 2½ feet in 60 rods	336·2–336·4	1081–1078½
Long Sault Rapids, descending 3 feet in ½ mile	342·9–343·1	1075–1072
Lake of the Woods, crossed 72 miles on the route to Lake Winnipeg and the Red River settlements, by way of the Winnipeg River	381·1–453·1	1060

SYSTEM OF THE RAINY AND WINNIPEG RIVERS.

LAKES ON THE INTERNATIONAL BOUNDARY, AND RAINY LAKE AND RIVER.

[From barometric observations by Prof. N. H. Winchell and Col. Charles Whittlesey, and from leveling by S. J. Dawson; corrected by comparison with subsequent railway surveys.]

	Feet above the sea.
Watershed between South and North Lakes, on the international boundary	1573
North Lake	1535
Gunflint Lake	1530
Saganaga Lake	1368
Otter Track Lake	1326
Knife Lake	1322
Basswood Lake	1244
Lac la Croix	1186
Namekan or Sturgeon Lake	1126
Rainy Lake, low and high water, approximately, 1115–1120; mean. The maximum depth of Rainy Lake, according to Dr. A. C. Lawson, is 110 feet.	1117
Vermilion Lake	1357
On Rainy River:	
Rapids at the mouth of Rainy Lake, about 3 feet	1117–1114
Falls of Rainy River (Chaudière Falls), at Fort Francis, 2½ miles below the mouth of Rainy Lake, 23 feet	1114–1091
A canal here, unfinished and perhaps never to be completed, is cut through rock (granitoid gneiss) 800 feet, about 40 feet wide, and was designed to have one lift of 24 feet 8 inches. Its cost to the Canadian Government has been $250,000. (Blue Book: Northwestern Ontario, its boundaries, resources, and communications. Toronto, 1879.)	
Mouth of Little Fork	1087
Mouth of Big Fork	1085
Manitou Rapids ("a short pitch over solid rock on the bottom and in both banks," N. Butler)	1081–1078
Head and foot of Long Sault Rapids, descending probably 7 feet in 1 mile	1075–1068
Mouth of Rapid or Winter Road River	1063
Lake of the Woods, low and high water, 1057–1063; mean	1060
Dr. G. M. Dawson states that this lake has a maximum depth of 84 feet in its northern part, which is called Clearwater Lake.	

SYSTEM OF THE RAINY AND WINNIPEG RIVERS—Continued.

BIG FORK OF RAINY RIVER.

[From Whittlesey's Report of Explorations in the Mineral Regions of Minnesota, 1866; corrected and referred to sea level approximately by comparison with elevations determined by leveling.]

NOTE.—This stream would be more properly named Bowstring River, which is the translation of its Ojibway name.

	From mouth of Big Fork (Whittlesey).	Above the sea.
	Miles.	*Feet.*
Bowstring Lake (United States engineers)	.....	1321
Head of "fall of 6 feet over trappose rock" (estimated by Whittlesey "about 70 feet" above the mouth of the Big Fork)	82	1240
"Rapid of 4 feet fall over hornblende slate"	75	1225
"Fall of 29 feet over gneiss and mica slate"	45	1179–1150
Mouth of the West Branch, "which heads near Red Lake"	40	1140
Junction with Rainy River	.....	1085

WEST BRANCH OF BIG FORK OF RAINY RIVER.

	Feet above the sea.
Highest (east) part of portage from Tamarack or Swamp River (a tributary of Red Lake) to Big Fork, about	1165
West Branch of Big Fork, at east end of this portage, "some 25 or 30 miles by the river and about 15 or 18 miles in a straight line" from its mouth (N. Butler)	1160
Junction with the Big Fork, about	1140

WINNIPEG RIVER.

[From leveling by S. J. Dawson, in 1857 and 1858, published in Hind's Narrative of the Canadian Exploring Expeditions, London, 1860, vol. 2, pp. 401 and 402; referred to sea level by comparison with the survey of the Canadian Pacific Railway. The difference in elevation between the Lake of the Woods and Lake Winnipeg determined by this survey agrees exactly with that found by the railway survey.]

	From the Lake of the Woods.	Above the sea.
	Miles.	*Feet.*
Lake of the Woods, low and high water, 1057–1063; mean	0·0	1060
Rat portage, 52 rods, descending 16 feet	0·0 0·2	1060 –1044
Les Dalles Rapids, descending 3 feet in ½ mile	8·25– 8·50	1043 –1040
Grand Décharge, descending 6 feet in ½ mile	33·55– 33·8	1038 –1032
Terre Jaune portage, 20 rods, descending 22 feet	35·7 – 35·8	1029 –1007
Charette Décharge, descending 3½ feet in 8 rods	36·5	1006½–1003
Terre Blanche portage, 40 rods, descending 8 feet	37·5 – 37·6	1002 – 994
Cave Rapids, descending 2½ feet in 8 rods	38·0	993½– 991
Mouth of English River, approximately	54·0	987
De l'Isle portage, 8 rods, descending 3½ feet	57·0	986½– 983
Chute à Jacques portage (Jack's Falls), 12 rods, descending 13 feet	80·1	979 – 966
Point des Bois portage, 52 rods, descending 10½ feet	89·7 – 89·9	964½– 954
Point aux Chênes portage (the Upper Falls), 20 rods, descending 20 feet	90·0 – 90·1	954 – 934
Roche Brulé portage, 12 rods, descending 8 feet	91·1	933 – 925
Slave Falls portage, 120 rods, descending 20 feet	95·5 – 95·9	924 – 904
Barrier Falls portage, 8 rods, descending 5 feet	102·0	902 – 897
Otter Falls, descending 3 feet in 4 rods	107.0	895 – 892
(Seven portages, successively 10, 8, 5½, 8, 3, 8, and 4½ feet, follow.)		
Foot of the seventh portage	116·2	826
Bonnet Lake, 4½ miles across on this route	127·6 –132·1	823
Bonnet portage, 4 rods, descending 7 feet	132·2	823 – 816
Cap de Bonnet portage, 16 rods, descending 5 feet	132·85–132·9	814 – 809

SYSTEM OF THE RAINY AND WINNIPEG RIVERS—Continued.

WINNIPEG RIVER—Continued.

	From the Lake of the Woods.	Above the sea.
	Miles.	*Feet.*
Big Bonnet portage, 200 rods, descending 34 feet	136·2 –136·8	805 – 771
Petit Roche portage, 52 rods, descending 8 feet	137·1 –137·3	770 – 762
White Mud portage, 60 rods, descending 13 feet	140·7 –140·9	758 – 745
Silver Falls (or Lower Falls), two portages, 92 rods, descending 22 feet	144·4 –144·7	744 – 722
Pine portage, 48 rods, descending 8 feet	150·25–150·4	720 – 712
At Fort Alexander	161·4	710
Mouth of river, Lake Winnipeg	163·2	710
Lake Winnipeg (determined by surveys for the Canadian Pacific Railway), low and high water, approximately	163·2	708 – 713

The distance traversed thence on the lake to the mouth of the Red River is 41 miles.

There are thus twenty-seven portages (the two décharges being included) between the Lake of the Woods and Lake Winnipeg.

Total length of canoe route, from Lake Superior, by Kaministiquia, Sturgeon, Rainy, and Winnipeg Rivers, to the mouth of the Red River of the North, 657 miles.

SYSTEM OF THE RED RIVER OF THE NORTH.

[From leveling by United States engineers, under the direction of Maj. Charles J. Allen, of St. Paul; from railroad surveys; and from the U. S. Geological Survey of Lake Agassiz.]

RED RIVER.

	Feet above the sea.
Lakes on the Otter Tail River, in northern and central Becker County (the highest sources of this head stream of the Red River of the North)	1500–1400
Otter Tail River, at Frazee (below the mill)	1360
Same, 4 miles southeast of Frazee	1340
Pine Lakes	1330
Rush Lake	1320
Otter Tail Lake (maximum depth, 40–60 feet)	1315
Star and Dead Lakes, about	1350
Lake Clitherall	1334
The maximum depth in the northeast part of this lake, according to soundings by Rev. C. M. Terry, is 44 feet, and in its southwest part 32 feet.	
East and West Battle Lakes	1328
The maximum depth of the former is about 40 feet, and of the latter 50 feet.	
Red River (bed), at the railroad bridge in Sec. 33, Aurdal	1230
Same, at the railroad bridge near the east line of the corporation of Fergus Falls	1193
Upper mill pond of Red River, Fergus Falls, above the Park Roller Mill, water	1195
(This mill has 15 feet head, with fall to 1,180 feet.)	
In Fergus Falls, at the bridge of the St. Paul, Minneapolis and Manitoba Railway, second mill pond, water	1178
(Two dams, successively with 12 and 10 feet head, are between the last and the next.)	
In Fergus Falls, at bridge of the Northern Pacific, Fergus and Black Hills (Northern Pacific) Railroad, bed, 1147; fourth and lowest mill pond, water	1156
(The total descent of the Red River in 3 miles at Fergus Falls is about 80 feet, from 1,210 to 1,130 feet above the sea.)	
Mouth of Pelican River, about	1115
At Dayton Bridge, near the north line of Sec. 29, Buse	1064
On the west line of Sec. 30, Buse	1041
Near the northeast corner of Sec. 33, T. 132, R. 44	1014
On the line between Otter Tail and Wilkin Counties	1000
Most southern bend of the Red River, in the northwest corner of Sec. 4, Bradford	990

	Feet above the sea.
At railroad bridge, 2 miles east of Breckenridge (bed)	956
At bridge of the St. Paul, Minneapolis and Manitoba Railway, 1 mile northeast of Breckenridge, water	951
Mouth of the Bois des Sioux River, Breckenridge and Wahpeton	943
Same, highest flood stage, about	958
(Lake Traverse, maximum depth about 15 feet, head of the Bois des Sioux River, low and high water	970–976
Bois des Sioux River, at White Rock, bed, 966; ordinary low water	968
Same, 2 miles east of Fairmount	963)
Connolly's Rapids, about 5 miles north of Breckenridge and Wahpeton, 1¼ miles long	936–932
At railroad bridge near foot of these rapids	931
At McCauleyville and Fort Abercrombie	910
Same, highest flood stage, about	934
(Surface of ground at Fort Abercrombie	937)
Mouth of Wild Rice River, North Dakota	875
(The foregoing, unless otherwise stated, denote the stage of ordinary low water.)	
At Moorhead and Fargo, bed, 862; ordinary low and high water, 870–885 or 890; extreme low and high water (range, 32 feet)	866–898
The lowest and highest stages of the river here during the years 1879, 1880, and 1882 were as follows, according to gauge records by United States engineers. The high water of 1882 has not been exceeded during many years and marks approximately the maximum limit of the most exceptional floods. In ordinary years the highest stage ranges from 880 to 890 feet. In 1879 the river remained nearly at its lowest stage throughout the year.	
1879, l. w., May 3, 866·33; h. w., July 15, 867·33.	
1880, l. w., Apr. 21, 869·40; h. w., Apr. 3, 879·73.	
1882, l, w., Oct. 3, 868 21; h. w., Apr. 12, 898·37.	
Mouth of Sheyenne River, ordinary low water	857
Mouth of Buffalo River, extreme low and high water, about	850–882
Mouth of Elm River, Quincy, ordinary low water	838
Extreme low and high water (range, 36 feet)	834–870
The lowest and highest stages of the river here during the years 1879, 1880. and 1882 were as follows, according to gauge records by United States engineers:	
1879, l. w., May, 833·70.	
1880, l. w., Oct. 13, 836·50; h. w., June 15, 844·10.	
(1881, h. w., May, about 860.)	
1882, l. w., Sept. 25, 836·63; high water April, 869·90.	
Mouth of Wild Rice River, Minnesota, ordinary low water, about	834
Mouth of Goose River, Caledonia, ordinary low water	822–824
Extreme low and high water (range, 40 feet)	821–861
The lowest and highest stages of the river here during the years 1880 to 1882 were as follows, according to gauge records by United States engineers:	
(1879, l. w., May, 821·3).	
1880, l. w., Oct. 4, 821·75; h. w., June 14, 829·05.	
1881, l. w., Aug. 20, 822·70; h. w., May, 850·90.	
1882, l. w., Sept. 28, 821·40; h. w., April, 860·90.	
Goose Rapids, shallow water, with the channel obstructed by bowlders, extending from the mouth of Goose River about 12 miles (measured in the meandering course of the Red River)	822–810
Mouth of Sand Hill River, about	800
At Belmont (formerly Frog Point), extreme low and high water (range, 50 feet)	797–847
Mouth of Red Lake River, Grand Forks, bed	779
Extreme low and high water (range, 44 feet)	784–828
The lowest and highest stages of the river here during the years 1882 to 1887 were as follows, according to gauge records by United States engineers:	
(1879, l. w., May, 785·40; 1881, h. w., May, 818.)	
1882, l. w., Sept. 24, 785·65; h. w., Apr. 17, 827·90.	
1883, l. w., Sept. 30, 787·40; h. w., Apr. 25, 822.10.	
1884, l. w., Aug. 18, 785·80; h. w., Apr. 16, 811·00.	
1885, l. w., Nov. 15, 785·70; h. w., Apr. 17, 803·00.	
1886, l. w., Oct. 5, 783·70; h. w., May 4, 800·50.	
1887, l. w., Nov. 20, 784·10; h. w., Apr. 15, 796·20.	

	Feet above the sea
Mouth of Turtle River, Sec. 11, T. 154, R. 51, ordinary low water	778
At Acton (formerly Kelley's Point), 2¼ miles north from the mouth of Forest River, ordinary low water	773
Mouth of Park River, St. Andrew, about	769
At Pelican Bar, ordinary low water	758
Mouth of Pembina River, Pembina and St. Vincent, bed	739
Ordinary low and high water	753–782
Extreme low and high water (range, 40 feet)	748–788
(Surface of ground at Fort Pembina	787)
At Emerson, ordinary low water and extreme high water	750–787
The following elevations of the Red River at Winnipeg and northward are derived from surveys for the Canadian Pacific Railway, being in considerable part from the published report of Sandford Fleming, engineer in chief, 1880, p. 269, from which a uniform subtraction of 6 feet is here made to accord with the revised profile of this railway.	
Mouth of Assiniboine River, Winnipeg, extreme low water	724
Ordinary summer stage	730
Ordinary spring floods	740–745
High water, 1882	750
Same, 1860	759
Same, 1852	761
Same, 1826	763
General level of the land surface	758
Extreme low and high water (range, 39 feet)	724–763
At the Louise Bridge, Winnipeg, extreme low water	723
Ordinary spring floods, about	740
High water, 1882	749
Same, 1826	763
General level of the land surface	756
Extreme low and high water (range 40 feet)	723–763
At St. Andrew's Church, extreme low water	715
Ordinary spring floods, about	735
High water, 1852	745
Same, 1826 (nearly the same as the general level of the land surface)	753
Extreme low and high water (range, 38 feet)	715–753
At Lower Fort Garry (the "Stone Fort"), extreme low water	711
Ordinary spring floods, about	730
High water, 1852	736
Same, 1826	746
General level of the land surface	752
Extreme low and high water (range, 35 feet)	711–746
At West Selkirk, extreme low water	710
Ordinary spring floods, about	720
High water, 1852	726
Same, 1826	732
General level of the land surface	739
Extreme low and high water (range, 22 feet)	710–732
At St. Peter's Church, general level of the land surface	730
Extreme low and high water (range, 15 feet)	709–724
Lake Winnipeg, mean	710
Extreme low and high water, approximately	708–713

(The maximum depth of Lake Winnipeg, according to Mr. J. Hoyes Panton, is 65 feet.)

From Otter Tail Lake to near Breckenridge the range of the Red River from low to extreme high water is only about 5 feet. Thence it rapidly increases, becoming 32 feet at Moorhead and Fargo and attaining its maximum of 50 feet at Belmont. It continues nearly at 40 feet from Grand Forks to the international boundary and Winnipeg. At Lower Fort Garry, 16 miles north of Winnipeg and about 20 miles from the mouth of the river, it is 35 feet; but beyond that point it rapidly diminishes in approaching Lake Winnipeg. Floods rising nearly or quite to the high-water line thus noted have been rare, occurring in 1826, 1852, 1860, 1861, and 1882. They are caused in the spring by the melting of unusual supplies of snow and by accompanying heavy rains, and often are increased by gorges of ice.

PELICAN RIVER.

	Feet above the sea.
One mile east of Detroit (mill pond)	1345
Detroit Lake	1335
Lakes Sallie and Melissa	1330
Pelican Lake (maximum depth about 40 feet)	1320
Cormorant Lake, about	1340
Lakes Lizzie and Lida	1315
[Lake Lida, according to soundings by Rev. C. M. Terry, ranges from 10 to 40 feet in depth.]	
Above and below the dam at Pelican Rapids	1303–1291
At railroad bridge, 1½ miles north of Erhart's Station	1269
At railroad bridge, 1 mile north of Elizabeth Station	1222
On the line between Elizabeth and Fergus Falls, estimated	1200
At the bridge of the St. Paul, Minneapolis and Manitoba Railway, in the east edge of Sec. 13, Carlisle	1151
At the bridge of the Northern Pacific, Fergus and Black Hills (Northern Pacific) Railroad	1124
Junction with the Red River, about	1115

BUFFALO RIVER.

Buffalo Lake, about	1400
At the most eastern railroad bridge, 3 miles east of Hawley	1150
At the railroad bridge, 0·4 mile east of Hawley	1131
At the railroad bridge, 4½ miles east of Glyndon	940
Same, 1½ miles north of Glyndon	908
Junction with the Red River, low and high water	850–882

WILD RICE RIVER, MINNESOTA.

Upper and Lower Rice Lakes, Twin Lakes, Tulaby, and White Earth Lakes	1500–1450
In the eastern part of Sec. 30, Fosum (T. 144, R. 43), about	1050
In the SW. ¼ of Sec. 25, Wild Rice (T. 144, R. 44), on line of survey for branch of the St. Paul, Minneapolis and Manitoba Railway	1025
At bridge of the Duluth and Manitoba Railroad, near Twin Valley	985
Two and a half miles south of Ada	900
Long Lake, at Ada, former channel of the Wild Rice River	901
[Thence westward this stream formerly flowed in the present course of the Marsh River.]	
Junction with the Red River, about	834

SAND HILL RIVER.

Maple Lake	1169
Near the center of Sec. 13, Garfield (T. 147, R. 44), on line of survey for branch of the St. Paul, Minneapolis and Manitoba Railway	1116
At bridge of the Duluth and Manitoba Railroad, in Sec. 28, Garfield	1075
At ford of the old Pembina trail, near the west line of this Sec. 28, Garfield	1071
At Beltrami	895
Junction with the Red River, about	800

RED LAKE RIVER.

Highest (east) part of portage, 6 miles long, from the West Branch of the Big Fork of Rainy River, about	1165
West end of this portage, ¼ mile above the forks of Tamarack or Swamp River, "about 18 miles by river, or 10 by land" from Red Lake (N. Butler), about	1155
Red Lake, estimated	1150
[The maximum depth of this lake, in its southern half, is 40 to 50 feet.]	
Mouth of Thief River	1099
At St. Hilaire, about	1065
Half a mile above the mouth of Clearwater River	948
Mouth of Clearwater River, Red Lake Falls	940

	Feet above the sea.
Clearwater River, below mill in west part of NE. ¼ of NE. ¼ of Sec. 22, Red Lake Falls	950
Same, ½ mile above (south of) this mill	965
[The range from low to high water of both Red Lake and Clearwater Rivers at Red Lake Falls is only 5 feet.]	
Red Lake River, at bridge of the Duluth and Manitoba Railroad	932
At Crookston railroad bridge, ordinary stage, 833; low and high water, about	830–850
Junction with the Red River, Grand Forks, bed, 779; low and high water	784–828

WILD RICE RIVER, NORTH DAKOTA.

Two miles west of Rutland	1202
At Ransom	1117
Taylor Lake (20 feet deep), 2½ miles west of the Lightning's Nest, about	1050
Swan Lake, 8 miles WNW. from the last, about	1070
Near the center of Sec. 25, T. 132, R. 52, 3½ miles south of Wyndmere, about	1010
At bridge on east line of SE. ¼ of Sec. 30, Berlin (T. 131, R. 49), most southern bend of the river	974
Four and a half miles west of Wahpeton	940
At bridge of the St. Paul, Minneapolis and Manitoba Railway, 1½ miles northeast from the last	936
Junction with the Red River	875

SHEYENNE RIVER.

Devil's Lake (having no outlet), low and high water, 1880–1889	1430–1434
Stump Lake (also having no outlet)	1417
At bridge of the Jamestown and Northern Railroad, near Sheyenne	1410
At Valley City	1200
At Lisbon	1064
In Sec. 32, T. 134, R. 54, 2 miles ENE. from its most southern bend	1039
On the west line of the NW. ¼ of Sec. 29, T. 135, R. 54	1021
At bridge near the middle of the south side of Helendale (T. 136, R. 52), about	960
At Kindred	930
At bridge of the Fargo and Southwestern Railroad	897
At Haggart	881
Mouth of Maple River, about	872
At railroad bridge, 1½ miles northwest of Harwood	862
Junction with the Red River	857

MAPLE RIVER.

At bridge of the Northern Pacific Railroad between Buffalo and Tower City	1130
In Sec. 32, T. 137, R. 54, about 2 miles northeast from its most southern bend	1019
At Durbin	904
At Mapleton	888
Junction with the Sheyenne River, about	872

ELM RIVER.

South Fork at Hunter	962
South Branch of the North Fork, 3½ miles south of Galesburg	1062
North Branch of the North Fork at Galesburg	1063
North Fork at Blanchard	927
Elm River at Grandin	865
North Branch at Kelso	888
Junction with the Red River, Quincy	838

GOOSE RIVER.

	Feet above the sea.
South Fork, near the southwest corner of Sec. 3, T. 145, R. 54, about.	1070
North Branch of the Middle Fork, where it intersects the Herman beach of Lake Agassiz, in the southeast part of Sec. 26, T. 147, R. 55, about	1085
Golden Lake (about 20 feet deep), low and high water	1122–1128
Fingal's Creek, where it intersects the Herman beach, northwest corner of Sec. 23, T. 148, R. 55, about	1110
Goose River and Little Goose River, where they intersect the Herman beach, respectively, in Secs. 35 and 15, T. 150, R. 55, about	1125
Goose River, at Portland, bed, 933; water	936
At Mayville, bed, 924; water held by dam	936
At Hillsboro, water	872
Junction with the Red River, Caledonia	822

TURTLE RIVER.

South Branch, where it intersects the Herman Beach of Lake Agassiz, in the SW. ¼ of Sec. 18, Elm Grove (T. 152, R. 55), about	1155
Same, 4 miles northwest from Larimore	1109
Same, at its most southern bend, 1½ miles north of Larimore, about.	1060
North Branch, at bridge in the east end of Bachelors' Grove, on the east line of the SE. ¼ of Sec. 30, Agnes (T. 153, R. 55)	1142
Same, at railroad bridge 2¾ miles north of McCanna (bed)	1115
Junction of South and North Branches, about	1030
Turtle River, 1½ miles north of Arvilla, about	950
Same, in Sec. 22, Mekinock (T. 152, R. 53), about	890–875
At bridge of the Duluth and Manitoba Railroad, near Mekinock Station	854
At Manvel, low and high water	798–812
Junction with the Red River, Sec. 11, Turtle River (T. 154, R. 51)	778

FOREST RIVER.

South and Middle Branches, where they intersect the uppermost shore of Lake Agassiz, west of the Elk Valley, about	1150
North Branch, at its intersection of this shore-line, near the center of Sec. 20, Vernon (T. 156, R. 56), about	1175
Junction of the South and North Branches, in Sec. 5, Inkster (T. 154, R. 55), about	1075
At railroad bridge, 1½ miles north of Inkster	941
At intersection of a beach of Lake Agassiz, in the east part of Sec. 2, Strabane (T. 154, R. 54), about	875
At bridge of the Duluth and Manitoba Railroad, near Forest Station	847
At Minto, low and high water	799–808
Junction with the Red River	774

PARK RIVER.

South Branch, at the Garfield bridge, about	1170
Same, in its course 1½ miles through "the mountains" east of the Golden Valley, about	1165–1115
Same, at Park River	964
Same, near the middle of the south side of Sec. 17, Fertile (T. 157, R. 54), about	880
Middle Branch, at bridge of the Langdon line, St. Paul, Minneapolis and Manitoba Railway	1243
Same, at middle of south side of Sec. 5, Lampton (T. 158, R. 56), about	1185
Same, in the southwest part of Sec. 12, Lampton, about	1075
Same, at bridge on east side of NE. ¼ of Sec. 29, Glenwood (T. 158, R. 54)	859
North Branch, at bridge about 1½ miles west of Gardar	1203
Same, in the west part of Sec. 13, T. 159, R. 56, 3 to 3½ miles east of Gardar	1025–1000
Same, at middle of east side of Sec. 5, Glenwood, about	865
Park River at Grafton, low and high water	809–819
Junction with the Red River, St. Andrew, about	769

TONGUE RIVER.

	Feet above the sea.
At bridge, near the center of the south half of Sec. 28, T. 161, R. 56, about	1110
At Mr. Abner French's, near the center of Sec. 18, T. 161, R. 55	994
At bridge, about 1 mile northeast from the last, about	970
At bridge, Cavalier	864
At Bathgate, bed, 801; low and high water	803–816
Junction with the Pembina River, about	770

PEMBINA RIVER.

Whitewater Lake, low and high water	1632–1637
At bridge of the Manitoba and Southwestern Railway, near Little Pembina Station, 68 miles west of Manitou	1605
Divide between the Souris and Pembina Rivers, in Lang's Valley (outlet of the glacial Lake Souris)	1364
Bone Lake, in Lang's Valley	1357
Grass Lake and Pelican Lake	1355
(Range of Pelican Lake, from low to high water, 3 feet.)	
Lakes Lorne and Louise, about	1345
Rock Lake, about	1335
At the Marringhurst bridge, about	1330
Swan Lake, about	1310
At bridge of Manitoba and Southwestern Railway, La Rivière	1287
At the Mowbray bridge, on the line between Secs. 21 and 22, T. 1, R. 8, Manitoba, about	1235
On the international boundary, about	1125
At the "fish trap," 7 miles west of Walhalla, N. Dak. (fall, 7 feet in ¼ mile), estimated about	1050–1043
At the Walhalla bridge, low and high water	934–943
At the St. Joseph bridge, 7 miles east from the last	865
At Neche, bed, 810; low and high water	813–832
Mouth of Tongue River, about	770
At bridge of the Duluth and Manitoba Railroad	757
Junction with the Red River, Pembina, extreme low and high water	748–788

ASSINIBOINE RIVER.

[From railway profiles; from the U. S. Geological Survey of Lake Agassiz; and from surveys by H. S. Treberne, engineer, St. Paul, referred to sea level by comparison with the Canadian Pacific Railway.]

	Feet above the sea.
At bridge of the Manitoba and Northwestern Railway, bed, 1,309; water	1314
Mouth of the Qu'Appelle River, about 17 miles south of the foregoing	1264
Fort Ellice, at top of the river bluff here	1484
At bridge of the Canadian Pacific Railway, 1¼ miles east of Brandon	1161
Mouth of Souris River, approximately	1100
At outcrop of Niobrara limestone in Sec. 36, T. 8, R. 11, about 3½ miles east from the mouth of Cypress River, approximately	1000
At Portage la Prairie, ordinary low and high water 2 miles southwest from the town, near the former site of the Hudson Bay Company's fort, 842–850; extreme high water, May 3–15, 1882, when the river overflowed here, sending part of its waters north to Lake Manitoba, 854	842–854
This rise was caused by an ice jam a few miles farther east. It is said that the river had previously overflowed here to Lake Manitoba about 20 years before [probably in 1860].	
Big Slough, occupying a deserted channel of the Assiniboine River close south of Portage la Prairie, ordinary stage of water, 849; in ordinary spring floods, 850; in the great flood of May, 1882, 854	849–854
At Pratt's Landing, 2½ miles southeast from Portage la Prairie, ordinary low and high water, 840-849; lowest and highest stages	837–852
Lake Manitoba, mean, 809; lowest and highest stages, approximately	805–813

	Feet above the sea.
Lowest portion of the divide between Lake Manitoba and Long Lake, approximately	812
Long Lake, 6 miles long and less than a mile wide, 6 inches to 6 feet deep, between Reaburn and Poplar Point Stations of the Canadian Pacific Railway, occupying a former channel of the Assiniboine River, ordinary low and high water	798–803
["The immediate banks of Long Lake are from 6 to 10 feet high, sloping up gradually."]	
Assiniboine River, at center of lot 142, Baie St. Paul, near the southeast end of Long Lake, top of river bank, 808; water, ordinary stage	796
In lot 230, Baie St. Paul, top of river bank, 794; water, ordinary stage	779
At St. Francois Xavier Church, top of river bank, 784; water, ordinary stage	765
At crossing of the "Winnipeg meridian," in Headingly, ordinary stage	757
At Headingly, 1½ miles farther east, ordinary low and high water	754–764
Mouth of Sturgeon Creek, ordinary stage	745
Sturgeon Creek at bridge about a half mile from the Assiniboine River	753
At St. James, ordinary low and high water	736–754
Junction with the Red River, Winnipeg, top of the river bank, 757; ordinary low stage of water (Oct. 1, 1874), 728; usual summer level, 730; usual spring flood, about 742; extreme low and high water	724–763

LAKES ON THE QU'APPELLE RIVER.

[From H. Y. Hind; referred to sea level approximately by comparison with elevations determined by leveling.]

	Feet above the sea.
Elbow of the South Saskatchewan River	1619
Ponds (about 10 feet deep) on the River that Turns	1686
Divide in ancient water course between the South Saskatchewan and Qu'Appelle Rivers (outlet of the glacial Lake Saskatchewan)	1704
Sand Hill or Eyebrow Lake (about 20 feet deep)	1685
Buffalo Lake (about 20 feet deep)	1635
Qu'Appelle River, at bridge of the Regina and Long Lake Railway	1595
Long Lake, tributary to the Qu'Appelle River	1598
Fishing lakes, four in number, with intervening descents of about a foot	1504–1500
The maximum depths of these lakes, successively in descending order, are 54, 57, 48, and 66 feet.	
Crooked Lake (maximum depth, 36 feet)	1389
Round Lake (maximum depth, 30 feet)	1364
Junction of the Qu'Appelle with the Assiniboine	1264

SOURIS OR MOUSE RIVER.

On the international boundary, crossing from Assiniboia into North Dakota, 215 miles west of the Red River, about	1650
At Minot, N. Dak	1535
At Towner, N. Dak	1445
Crossing the international boundary, 170 miles west of the Red River, about	1400
At Plum Creek, Manitoba, about	1335
At the Elbow west of Lang's Valley, 21 miles ESE. from the last, about	1265
At Gregory's Mill, in Sec. 34, T. 6, R. 18, 5 miles north from the last, head, 8 feet, about	1210–1202
At Souris City	1164
At Milford	1114
Junction with the Assiniboine River, about	1100

SASKATCHEWAN RIVER.

[From surveys of the Canadian Pacific Railway; of the Geological and Natural History Survey of Canada, by Dr. G. M. Dawson, R. G. McConnell, and J. B. Tyrrell; and of the Assiniboine and Saskatchewan Exploring Expedition, by H. Y. Hind.]

	Feet above the sea.
Bow River at the Gap, where it issues from the Rocky Mountains, about	4215
Same, at Calgary, mouth of the Elbow River	3390
Same, at the Blackfoot crossing, near center of T. 21, R. 21	2595
Belly River at the "Coal Banks," Lethbridge	2717
Confluence of the Bow and Belly Rivers, forming the South Saskatchewan	2212
South Saskatchewan River at Medicine Hat, low and high water	2137–2154
Same, at mouth of Red Deer River	1958
Same, in T. 22, R. 18, long. 108° 27′	1782
Same, at the Elbow	1619
North Saskatchewan River at the Rocky Mountain House and mouth of Clearwater River, about	3150
Same, mouth of Brazeau River	2661
Same, at big coal seam (27 feet thick, but including 2 feet of shale), Goose Encampment, long. 114° 30′	2331
Same, at proposed crossing of the original line of the Canadian Pacific Railway, long. 114°, about	2160
Same, at Edmonton, about (Edmonton, 200 feet above high-water level of the river, about 2,235.)	2025
Same, at Victoria, near mouths of Egg and Smoky Creeks	1895
Same, at Fort Pitt	1746
Junction of the South and North Saskatchewan Rivers, estimated	1200
Cedar Lake	824
Cross Lake	818
Head and foot of Grand Rapids of the Saskatchewan River, extending from about 4¼ to 2 miles above its mouth (fall stated by Hind to be 43¼ feet in these 2¼ miles, the upper 28¼ feet being passed by a portage a little more than a mile long), approximately	765–720
Lake Winnipeg, mean, 710; low and high water, approximately	708–713

NELSON RIVER.

The following estimated elevations of points on the Nelson River are by Dr. Robert Bell (Reports of Progress, Geological Survey of Canada, 1877–'79).

	Feet above the sea.
Lake Winnipeg	710
Great and Little Playgreen Lakes, also	710
Sea River Falls, 17 miles below Norway House, about	705–700
Pipestone and Cross Lakes, on the Nelson River at the north end of Ross Island, about	665
Sipi-wesk Lake, on Nelson River from lat. 55° to 55° 20′, about	565
Grand Rapid, "a descent of about 15 feet in the form of a steep chute," 4 miles south of Split Lake, about	460–445
Split Lake, in lat. 56° 15′ to 56° 35′, about	440
Gull Lake, 18 miles below (ENE. of) Split Lake, about	420
Twelve-foot chute, 43 miles below (east of) Gull Lake, about	200–188
Foot of Broad Rapid, "2 miles wide and full of knobs and little ridges of gneiss," extending 5 miles next below the Twelve-foot chute, or 116 to 111 miles from the mouth of Nelson River, about	125
Foot of First or Lowest Limestone Rapid, about 90 miles by the course of the river above its mouth, probably about	50

The effect of the tide extends to Gillam's or Lower Seal Island, which is about 20 miles from Hudson Bay. Spring tides on the west coast of Hudson Bay are quite uniformly 11 or 12 feet, being greater than on the east coast. They are highest at the mouth of the Nelson River, amounting there to about 15 feet.

The average depth of Hudson Bay is "about 70 fathoms throughout, deepening to 100 and upwards in approaching the outlet of Hudson's Strait; while in the strait itself the soundings along the center vary from about 100 to upwards of 300 fathoms. The bottom appears to consist almost everywhere of bowlder clay and mud."—Dr. Bell, in Can. Geol. Surv., Rep. of Prog. for 1879–'80, pp. 29–30 C.

ALTITUDES OF WATERSHEDS, HILLS, MOUNTAINS, LAKES, AND STREAMS, ON ROUTES OF GEOLOGICAL OR OTHER SURVEYS.

ADDITIONAL NOTES FROM RAILROAD SURVEYS IN MINNESOTA.

CARVER COUNTY.

[From E. S. Alexander, engineer, Minneapolis.]

	Feet above the sea.
Lake Lucy, Chanhassen	954
Minnewashta Lake	945
Picture or Mud Lake, Watertown	940
South Fork of Crow River, above and below the dam at Watertown	927–920
Bluff on east side here	976
Ocean marsh, Secs. 7 and 8, Hollywood	999

McLEOD COUNTY.

[Also from E. S. Alexander, engineer, Minneapolis.]

Winsted Lake	996
Swan Lake	1047

OLMSTED COUNTY.

[From Horace Horton, engineer, Rochester.]

Top of Lone Mound, Sec. 11, Farmington	1175
Base of Sugar Loaf, Secs. 31 and 32, Haverhill	1033
North Middle Branch of Zumbro River at Oronoco	958
Center of Sec. 21, Oronoco	1108
Quarter-section stake between Secs. 33 and 34, Oronoco	1133
Northwest corner of Sec. 10, Cascade	1143
Creek near the schoolhouse in Sec. 15, Cascade, about	1008
College street bridge, Rochester	983
South Branch of Zumbro River here	968
Southeast corner of Sec. 10, High Forest	1310
Low water in the North Branch of Root River at High Forest village	1213
Pleasant Grove, about	1310

MOWER COUNTY.

[Also from Horace Horton, engineer, Rochester.]

Section 29, Pleasant Valley, ¼ mile south of John Rowley's house	1400
Dr. Thornhill's farm, 4 miles east of Brownsdale	1373

FREEBORN COUNTY.

[From William Morin, engineer, Albert Lea.]

Geneva Lake	1222
Clark's Grove, 3½ miles southwest from Geneva Lake	1322

CHAINS OF LAKES IN MARTIN COUNTY.

[The partially filled ancient water courses in which these lakes lie are probably interglacial. Geology of Minnesota, vol. I, pp. 479–485.]

	Feet above the sea.
East chain of lakes (maximum depths, about 15 feet)	1160–1180
Central chain of lakes (8 to 50 feet deep)	1165–1190
West chain of lakes (5 to 20 feet deep)	1200–1250

ST. PAUL AND VICINITY.

[From F. W. McCoy, assistant city engineer; and from surveys for railways and water works.]

	Feet above the sea.
Zero of Signal Service gauge, Mississippi River, at foot of Jackson street	682·53
Zero of gauge on pier of the Wabashaw street bridge	682·52
Zero of city levels	692·60
Mississippi River, extreme low water (1864 and Dec., 1878, Maj. C. J. Allen)	683
Same, lowest stage in ordinary years	685
Same, extreme high water (Apr. 29, 1881, Major Allen)	702
Union depot	703
Robert street bridge, highest part of roadway (level span, 352 feet long)	763
Intersection of Wabashaw and Third streets (3 or 4 feet above the north end of the Wabashaw street bridge)	787
South end of the Wabashaw street bridge	713
Intersection of Wabashaw and Tenth streets, at the northwest corner of the capitol ground	796
Summit of Dayton bluff, intersection of Seventh and Hope streets, natural surface, 915; grade	899
Summit of Robert street at its junction with Jackson street, natural surface, 897; grade	879
Summit of St. Anthony hill, on Summit avenue, between Arundel and Lawton streets, grade	926
The following elevations of lakes near St. Paul and northward are from a Report on Plans for the Water Supply of St. Paul, by Joseph P. Frizell, 1882, and from railway surveys.	
Lake Phalen	859
Lake Como	885
Lake Elmo (Lower Bass Lake)	886
Upper Bass Lake	900
Sandy Lake, Sec. 18, New Canada	869
Vadnais Lake	881
Pleasant Lake	891
White Bear Lake	923
Bald Eagle Lake	908
Clearwater Lake, Centerville	885
Clear Lake, ¼ mile southwest of Forest Lake	889
Forest Lake, 24 miles north of St. Paul	900

MINNEAPOLIS AND VICINITY.

[Mostly from profiles in the office of Andrew Rinker, city engineer.]

	Feet above the sea.
Zero of city levels	708·64
Mississippi River, crest of St. Anthony Falls, ordinary stage of water held by dams, 794; highest stage of flowage by dams, 796; highest stage of floods, 802	794–802
Same, close below the falls, under the east end of the St. Paul, Minneapolis and Manitoba stone arch bridge	739–743
Same, 1 mile below the falls, under the St. Paul and Northern Pacific bridge	720
St. Paul, Minneapolis and Manitoba (union) depot	810
Chicago, Milwaukee and St. Paul depot, Washington avenue	826
Old suspension bridge, roadway at abutments and center	832–835
New steel arch bridge, roadway, rising 3 feet from abutments to center over the pier	833–836
Same, bottom of pier, 777; top of same, of capstone beside the roadway	837
Same, bed of river (gravel), 784; ordinary stage of water	794
Washington avenue bridge over Bassett's Creek	818
Intersection of Hennepin and Lyndale avenues	854
Franklin avenue, at intersection of Nicollet avenue, 873; of Fourth avenue, 862; of Cedar avenue	839
University avenue, at intersection of Central avenue, 837; of Fourteenth avenue SE	827

	Feet above the sea.
State University, about	845
Intersection of Monroe street and Broadway, NE	843
Southwest end of Hennepin avenue, on Thirty-sixth street, at gate of Lakewood Cemetery	879
Top of highest hill in Lakewood Cemetery, site of deep boring (unsuccessful) for artesian well, 1884–'85	895
Cedar Lake	857
Lake of the Isles	852½
Lake Calhoun	852
Lake Harriet	845
(The elevations of this series of four lakes in the southwest part of Minneapolis were all taken the same day in October, at their stage of low water. The maximum depth of Lake Harriet, said to be the deepest of these lakes, is 80 feet.)	
Lake Minnetonka (maximum depths, 40 to 70 feet) ordinary stage, 927–8; low and high water	925–929

NORTHEASTERN MINNESOTA.

[Mostly determined barometrically by Prof. N. H. Winchell, State geologist.]

LAKE SUPERIOR TO VERMILION LAKE (a).

[From the Ninth Annual Report of the Geological and Natural History Survey of Minnesota; corrected approximately by comparison with series *b* and *c*, and with the survey of the Duluth and Iron Range Railroad.]

	Feet above the sea.
Lake Superior	602
Summit of the portage, 5 miles from Grand Portage village	1284
Pigeon River, at north end of this portage	1199
South Fowl Lake	1435
Hills near this lake	1760–1860
North Fowl Lake	1439
Moose Lake	1487
Hill 1½ miles southwest of Moose Lake	1970
Mountain Lake	1652
Hill south of the narrows of Mountain Lake	2003
Watershed between Pigeon and Arrow Rivers on the international boundary	1670
Rove Lake	1649
Daniels Lake	1621
Birch Lake	1645
Hungry Jack Lake	1652
Bearskin Lake	1680
Fanny Lake	1672
Lake Miranda	1733
Pine Lake	1454
McFarland's Lake	1453
John Lake	1452
Caribou Lake	1549
Clearwater Lake	1661
(Mountain Lake, determined from the last, was found to be 1,656, proving approximate accuracy for the circuit of the foregoing 15 observations.)	
Mud or Rose Lake	1500
Rat Lake	1506
South Lake	1535
North Lake, also	1538
Watershed between South and North Lakes, *i.e.*, between the basins of Lake Superior and Lake Winnipeg	1573
Gunflint Lake	1530
Banks's Pine Lake	1385
Saganaga Lake	1368
Otter Track Lake	1326
Knife Lake	1322
Maple Leaf Lake	1319
Sucker or Carp Lake	1289
Basswood Lake	1244
Kawasachong or Fall Lake	1262

	Feet above the sea.
Long Lake	1325
Burnt-side Lake	1356
Mud Lake	1370
Vermilion Lake	1357
Pike River above its third rapids	1390

LAKE SUPERIOR TO HUNGRY JACK LAKE (*b*).

[From the Tenth annual report of the Geological and Natural History Survey of Minnesota (with Plate II); corrected approximately by comparison with series *d*.]

	Feet above the sea.
Lake Superior	602
Summit 1½ miles from Grand Marais on the trail to Rove Lake	1387
Summit 1½ miles from Grand Marais on the "Iron Trail"	1665
Lake at head of the South Branch of Devil's Track River	1617
Devil's Track Lake	1647
Watershed between this and Tamarack Lake	1750
Tamarack Lake	1715
Owl Lake	1731
Little Pine Lake	1737
Clubfoot Lake	1756
Round Lake	1791
Lake Abita	1932
Brulé Mountain	2044
Lakes of Brulé River north of this mountain	1538
Little Lake (south of the Misquah Hills)	1782
Hills surrounding Little Lake, about	2000
Little Trout Lake	1855
Misquah Lake	1840
Misquah Hills, northeast and east of Misquah Lake	2300–2400
Cross Lake	1810
North Brulé Lake	1799
Caribou Lake	1821
Little Lake (north of the Misquah Hills)	1824
Poplar Lake	1804
Duck Lake	1827
Portage Lake	1817
Iron and Mayhew Lakes	1796
Hungry Jack Lake	1652

SAGANAGA LAKE TO LAKE SUPERIOR (*c*).

[From the Tenth annual report of the Geological and Natural History Survey of Minnesota (with Plate I); starting with the elevation of Saganaga Lake from series *a*, and corrected approximately by the elevation of Lake Superior.]

	Feet above the sea.
Saganaga Lake	1368
Town Line Lake	1451
Ogishkie Muncie (or Kingfisher) Lake	1461
Twin Peaks, south of Ogishkie Muncie Lake, about	1950
Fox Lake	1509
Ash or Agemok Lake	1568
Gobbemichigomog Lake	1578
Crooked Lake	1585
Little Saganaga Lake	1593
East-and-West Lake	1599
Lower Lake in Frog Rock River	1609
Upper Lake in Frog Rock River	1626
Watershed between this and Mesabi Lake	1776
Mesabi Lake	1681
Hills west and south of Mesabi and Duck Lakes, about	1875
Duck Lake	1691
L Lake	1756
Wind Lake	1816
Spotted Rock Lake	1863
Mesabi Range south of Spotted Rock Lake	2019
Young Sawbill Lake	1797
Rat Lake	1802
Burntwood Lake	1782

	Feet above the
Temperance River Lake	
Lake in Poplar River	
Square Lake	
Small Lake	
Camp Lake	
Smoke Lake	
Sunrise Lake	
Rice Lake	
Big Lake	
Sucker Lake	
Lake Superior	

LAKE SUPERIOR TO IRON LAKE (*d*).

[Barometric observations by E. LeM. Hoare in a reconnaissance for a proposed railroad, as r in the Tenth annual report of the Geological and Natural History Survey of Minnesota, p. 85 (Plate II); corrected approximately by comparison with series *b*.]

	Feet above the
Lake Superior	
South Branch of Devil's Track River	
Devil's Track River	
Devil's Track Lake	
Summit north of the Twin Lakes, in the SW. ¼ of Sec. 25, T. 63. R. 1 W	
Iron and Mayhew Lakes	

RAINY LAKE TO KNIFE FALLS ON THE ST. LOUIS RIVER.

[From the notes of Col. C. Whittlesey and Prof. N. H. Winchell; referred to sea level approxim by leveling by S. J. Dawson, compared with the Canadian Pacific Railway, and by the eleva of Vermilion Lake and the Embarras River determined in the survey of the Duluth and Range Railroad.]

	Feet above the
Rainy Lake, low and high water, about 1115–1120; mean	
Namekan or Sturgeon Lake	
Sand Point Lake in Vermilion River, about	
Crane Lake in Vermilion River, about	
("From marks observed on Crane, Sand Points, Nemakan, and Rainy Lakes, their waters appear to rise at some seasons to about 5 feet above their present level." [This was Sept. 5–9, 1848.]—Norwood in Owen's Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, pp. 318, 319.	
Crane Lake portage, close above Crane Lake, has an ascent of 35 feet in 1 mile; and another portage a mile long, close below Rush Lake, ascends 78 feet.)	
Rush Lake in Vermilion River, 8 miles below Vermilion Lake, about	
Vermilion Lake	
Pike River at the northwest end of the portage to Embarras River, about	
Summit of portage, about	
Embarras River (lake-like) at the southeast end of this portage, about	
Lake about 5 miles long and ¼ mile wide, having its mouth at the Squagemaw bridge (in Sec. 5, T. 58, R. 15), about	
Mesabi Range on both sides of this lake, extending ENE., (named "Giant's Range" by Prof. N. H. Winchell in his Thirteenth annual report, Minnesota, p. 22)	1750–
(Where the Embarras River intersects the Mesabi (or Giant's) Range, it consists of a series of six or seven long and narrow lakes; indicating that a larger river flowed here during the recession of the ice-sheet, its deeply eroded channel having since been partially filled by alluvium from tributaries.)	
Lake next below the Squagemaw bridge, about	
Second lake below this bridge, "separated by narrows like a river into two parts," about	
Eshquagema (Squagemaw, i. e., last) Lake, about	
St. Louis River at mouth of East Savanna River (Whittlesey)	
Prairie Lake, 9 miles south from the last (Winchell), about	
Head of rapids above Knife Falls, St. Louis River	

VARIOUS TOPOGRAPHIC DISTRICTS IN MINNESOTA.

	Feet above the sea.
Giant's Range, about 15 miles southeast of Vermilion Lake (according to Prof. N. H. Winchell), and extending thence east-northeastward to the north side of Gunflint Lake	1800–2200
Mesabi Range, about 20 miles southeast of Vermilion Lake (Winchell) and extending east-northeastward to the watershed between South and North Lakes, attaining the highest elevation in the State	1800–2400
The Misquah Hills, 2,300 to 2,400 feet (p. 185), are outliers of this range several miles south from its main course, which passes from South and North Lakes eastward to Mountain Lake.	
Sawteeth Mountains, near the shore of Lake Superior, from Temperance River to Grand Marais	1300–1700
Carlton's Peak, one of the Sawteeth Mountains, 1,542 (Owen), 1,529 (Hall).	
Great Palisades (Bayfield, quoted by Whittlesey)	1055
Wooded region of the Upper Mississippi River	1200–1600
Wooded region between Cass Lake and the Lake of the Woods	1400–1100
Lowest part of the watershed between Lake Winnebagoshish (1,290) and Bowstring Lake (1,321), on the head stream of the Big Fork of Rainy River (Whittlesey)	1322
Bowstring Lake, in its highest stage, is said to have "water connection" to Lake Winnebagoshish (Ninth An. Rep., Minn., p. 194).	
Lowest part of the watershed between Turtle Lake and Red Lake, only 11 feet above Cass Lake (Whittlesey)	1311
Adjacent hills are 72 feet higher	1383
Itasca Lake	1462
Wooded morainic hills south and west of Lake Itasca	1500–1700
Terminal moraine at White Earth Agency	1600
Same, east of Detroit	1450–1500
Same, east of Lake Lida	1425
Same, east of Fergus Falls	1300
Leaf Hills	1400–1750
Terminal moraine bordering Lake Whipple (1,135), at Glenwood	1250–1400
Blue Mounds, Pope County	1250–1300
Summit of highland in the northeast part of Langhei, Pope County, about	1350
Morainic hills surrounding Lake Minnetonka (927), about	1000
Kiester Hills, Faribault County	1300–1400
Blue Mounds, Cottonwood County	1450–1525
Coteau des Prairies, in Pipestone and Lincoln Counties	1850–1960
Red River flat at St. Vincent	785–790
Same, at mouth of Red Lake River (Grand Forks)	830
Same, at Moorhead and Fargo	900–905
Same, at Breckenridge and Wahpeton	960
Prairies of the Minnesota Valley	1000–1200
Same, of Waseca and Steele Counties	1100–1300
Same, of Freeborn and Mower Counties	1200–1400
Valley lands of the Mississippi River and its tributaries in Houston, Fillmore, Winona, Wabasha, and Goodhue Counties	640–900
Upland prairies of the same counties	1000–1300

MORAINIC BELTS IN IOWA.

Terminal moraine in Worth and Winnebago Counties	1250–1350
Pilot Mound, Hancock County, about	1425
Terminal moraine extending thence northwest to Fairmont, Minn.	1325–1225
Same, west to Lake George	1250–1300
Same, in Wright and Franklin Counties	1350–1200
Same, in Hardin and Hamilton Counties	1250–1150
Mineral Ridge, in northern Boone County, about	1200
Terminal moraine in Guthrie and Carroll Counties	1200–1325
Same, in Sac and Buena Vista Counties	1275–1500
Same, in Palo Alto, Clay, Emmet, and Dickinson Counties	1300–1600
Spirit Lake, 1,395; morainic hills west of same	1475–1525
Terminal moraine in northeastern Osceola County	1550–1675

PLATEAUS, HILLS, AND LAKES IN SOUTH AND NORTH DAKOTA.

	Feet above the sea.
Coteau des Prairies, from the west line of Lincoln County, Minn., to its northern end, called the Head of the Coteau des Prairies, near the northeast corner of South Dakota, 35 miles west of Lake Traverse	1900–2050
Terminal moraines continuing thence northward through North Dakota to Devil's Lake and Turtle Mountain, mostly	1400–1600
Devil's Lake, low and high water, 1880–1889	1430–1434
(The maximum depths of the broad parts of this lake are 40 to 80 feet.)	
Devil's Heart Hill (determined barometrically by Nicollet)	1722
Sully's Hill (according to Andreas' Atlas of Dakota)	1707
Stump Lake (maximum depth, 75 to 100 feet), 7 miles southeast of Devil's Lake	1417
Sweetwater Lake (5 to 20 feet deep), 5 miles north of the city of Devil's Lake	1468
Crest of the First Pembina Mountain, near Walhalla, the eroded front of the Pembina delta of Lake Agassiz	1175–1200
Crest of the Second Pembina Mountain, a great escarpment 60 miles long, forming the eastern margin of a plateau or plain of the Fort Pierre shale	1400–1500
Turtle Mountain (according to Dr. G. M. Dawson's map)	2150
Same (according to profile in report of the United States Boundary Commission)	2000–2534
Butte St. Paul, highest point of Turtle Mountain, 700 feet above the general prairie level (according to Andreas' Atlas of Dakota).	2300
Bear Butte, Turtle Mountain (Andreas)	2200
Terminal moraine from the head of the Coteau des Prairies to the Coteau du Missouri, in Codington, Hamlin, Brookings, and Lake Counties, South Dakota	1800–1900
Coteau du Missouri, thence northward to the Northern Pacific Railroad	1800–2200
Same, in the northwest part of North Dakota and on the international boundary	2000–2400

BLACK HILLS.

[From Newton and Jenney's Report on the Geology and Resources of the Black Hills of Dakota, 1880.]

	Feet above the sea.
Harney Peak, highest point of the Black Hills	7368
Crook Tower	7325
Terry Peak	7215
Custer Peak	6932
Warren's Peak (Jenney in Gannett's Dictionary of Altitudes)	6900
Inyan Kara, 6,870 (p. 553, but 6,563 on p. 552).	
(The heights of these peaks above adjoining valleys at their base are 1,000 to 2,000 feet.)	
Junction of the South and North Forks of the Cheyenne River	2470

ON THE INTERNATIONAL BOUNDARY.

[From reports of N. H. Winchell, H. Y. Hind, G. M. Dawson, R. G. McConnell, and the United States Northern Boundary Commission; referred to sea level by comparison with railway surveys.]

	Feet above the sea.
Lake Superior, low and high water, 599–604; mean	602
Mountain Lake, at head of Pigeon River	1652
South Lake, at head of Arrow River	1535
Water divide on the boundary, between South and North Lakes	1573
North Lake, at head of waters draining to Rainy Lake	1535
Gunflint Lake	1530
Saganaga Lake	1368
Otter Track Lake	1326
Knife Lake	1322
Basswood Lake	1244
Lac la Croix (or Nequanquon Lake)	1186
Namekan Lake	1126
Rainy Lake, low and high water, 1115–1120; mean	1117

	Feet above the sea.
Lake of the Woods, low and high water, 1057–1063; mean	1060
Ridge 12 miles farther west, forming the watershed on the boundary between the Lake of the Woods and Roseau Lake	1088
Muskeg (swamp), forming other parts of this watershed, about	1075
Pine River	1047
Roseau Lake, about	1040
Ridge 3 miles west of Pine River	1070
Roseau River at Pointe d'Orme	976
Ridge 20 miles east of the Red River	1016
Ridge 12 miles east of the Red River	848
Emerson	790
Red River, low and high water, 747–787; ordinary stage	752
Gretna	829
Pembina Mountain, base and top	1030–1500
Pembina River, approximately	1125
General level of the adjoining country, about	1540
Lac des Roches in North Dakota and divide between this lake and Badger Creek in Manitoba, about	1520
Turtle Mountain (according to Dr. G. M. Dawson's map)	2150
Same (according to profile in report of the United States Boundary Commission)	2000–2534
Souris River, first crossing, about	1400
Same, second crossing, about	1650
Coteau du Missouri, base and crest	1900–2140
Wood Mountain, highest portion on the boundary	2950–3075
Same, north of the boundary	3350
White Mud River	2550
Boundary Plateau	3000–3250
East Fork of Milk River	2790
Wild Horse Lake	2850
Milk River, probably about	2600
West Butte, the highest of the Sweet Grass hills or Three Buttes	6483
East Butte	6200
Trail from Fort Benton to Fort MacLeod	3548
North Branch of Milk River 1 mile north of the boundary, long. 113°	4173
Eastern base of the Rocky Mountains, long. 113° 25′, about	4500
Waterton Lake (or Chief Mountain Lake), crossed by the boundary in long. 113° 52′, in the east edge of the Rocky Mountains	4245
Rocky Mountains, summits in the vicinity of this lake, on the continental watershed	7500–10500

MANITOBA AND ADJOINING PARTS OF BRITISH AMERICA.

NORTH, NORTHEAST, AND NORTHWEST OF LAKE SUPERIOR.

[Mostly from reports of the Geological and Natural History Survey of Canada; in part corrected approximately by comparison with the survey of the Canadian Pacific Railway.]

	Feet above the sea.
Lake Superior	602
McKay's Mountain (Bayfield, quoted by Whittlesey)	1824
Mountains west of Thunder Bay (S. J. Dawson)	1600
Thunder Cape, east of Thunder Bay (S. J. Dawson)	1950
Mount Cambridge, on St. Ignace Island, south of Nepigon Bay, not the highest point of the island (Agassiz), about	1600
Kakabeka Falls, according to Keating and Agassiz, have a vertical descent of about 130 feet, the breadth of the Kaministiquia River there being about 50 yards, as stated by Keating, but about 150 yards by Agassiz. Captain Palliser, who visited this fall June 18, 1857, reports it as 115 feet high, with a breadth of 335 feet. Leveling by S. J. Dawson in August, 1857, found this fall and the rapids below together 119 feet. Of this the rapids, three-fourths of a mile long, are about 14 feet.	
The falls of Pigeon River, on the international boundary, are stated by Hind to be 120 feet high; this probably includes the rapids below to Lake Superior. Norwood says it "descends perpendicularly 60 feet."	
Lake Mistassini, about	1350
(Soundings in this lake show a depth of 374 feet.)	

	Feet above the sea.
Lake Mistassinis (Little Mistassini), east of the foregoing, about..	1370
Lake Abittibi, about	857
Height of land portage south of the east end of Lake Abittibi, on the route to Lac des Quinze on the Ottawa River, about	957
Lake Nipissing (Canadian Pacific Railway, from Dr. Bell)	638
Missinaibi Lake, near the head of Missinaibi River, the western branch of the Moose River system, about	1020
"Missinaibi Lake bears S. 48° W., is 24 miles long, nearly straight, and varies from ¼ to 1½ miles in width." (Rep. of Prog., Can., 1875–'76, p. 330.)	
Crooked Lake, close southwest of Missinaibi Lake, about	1038
"It is 8½ miles long, and averages less than a quarter of a mile in width."	
Height of Land Portage between Crooked and Dog Lakes, approximately	1042
Dog Lake, about 1 foot above the next	1026
Mattagaming or Mattawagaming Lake, on the Upper Michipicoten River (Canadian Pacific Railway, from Dr. Bell)	1025
Lake Manitowick, on Michipicoten River, about	943
McKay's Lake, at the head of Pic River, 12 miles long and 2½ miles wide	1064
Kenogami or Long Lake, at head of Kenogami River, tributary to Albany River (Canadian Pacific Railway, from Dr. Bell)	1032
This lake is 54½ miles long, and is mostly from ¼ mile to 2 miles wide.	
"The average breadth of the main section, 46 miles in length, found by taking the mean of 15 measurements, at equal distances, is 104 chains, or a little over a mile and a quarter." (Rep. of Prog., Can., 1871–'72, p. 336.)	
Dr. Bell states in a letter that the summit crossed by the Height of Land Portage close south of this lake, and leading from it to Black River, is about 70 feet higher, being therefore approximately 1,102 feet above the sea. This portage "is about ¼ mile long, and is over an accumulation of well-rounded bowlders with gravel and earth filling the interspaces in part; at other parts the bowlders are piled on each other quite naked." The valley between the rocky walls is about half a mile wide. The surface is somewhat level and there is a subordinate valley or depression sweeping around on the west side between the bulk of the accumulation of bowlders and the rocky bluff on that side." The ancient water course thus described west of the portage is probably only a few feet above Kenogami Lake, having very nearly the same elevation as the divide between the Missinaibi and Michipicoten Rivers. Both these low points of the watershed were doubtless occupied by rivers outflowing from glacial lakes on the north during the recession of the ice sheet.	
The following (to Mountain Lake, inclusive) are northwest of Long Lake House, which is at the north end of Kenogami or Long Lake:	
Manitou-namaig Lake, about 18 miles long, and from 12 rods to 1½ miles wide	1052
Round Lake, half a mile from the last, also	1052
Muddy Lake	1064
Fleming's Lake	1107
Ka-wa-kash-ka-ga-ma Lake	1088
Egg Lake	1112
Mountain Lake	1119
Lake Nepigon (540 feet deep near Echo Rock)	915
Great Dog Lake, 25 miles northwest of Thunder Bay	1350
Depressions in the line of watershed northwest of Lake Superior ..	1500–1750
Lac des Mille Lacs	1485
Shebandowan Lake, southeast of the last (S. J. Dawson)	1465
Kashaboiwe Lake, between the last two (S. J. Dawson)	1494
Lonely Lake (Lac Seul)	1232
This altitude, determined independently, probably requires some subtraction, for the description of the canoe route from Lonely Lake to Lake St. Joseph shows that the latter is the higher, the difference being apparently 20 feet or more.	

	Feet above the sea.
Lake St. Joseph (mean of ten barometric observations on as many days)	1172
Lake Lansdowne, near the head of the Attawapishkat River, about	960
Lake Winnipeg, mean	710
Low and high water, approximately	708–713
Lake St. Martin (maximum depth 18 feet)	794
Lake Manitoba, mean, 809; low and high water, approximately	805–813
Lake Winnipegosis, mean, 828; low and high water, approximately	825–831
Lake Dauphin	839
Swan Lake (mean depth, 6 feet), about	860
Watershed between Lake Winnipegosis and Cedar Lake	875
Cedar Lake, on the Saskatchewan	824
Butte St. John, the highest point of Turtle Mountain in Manitoba (Andreas)	2200
Pembina Mountain, crest of the escarpment	1400–1500
Tiger Hills	1500–1600
Big Tiger Hill, north of Lang's Valley, about	1640
Brandon Hills	1550–1600
(The four preceding are from the United States Geological Survey of Lake Agassiz.)	
Riding Mountain, about	2000
Duck Mountain	2300–2700
Thunder Hill	1900
Porcupine and Pasquia Hills, about	2000
Long Lake, west of Last Mountain	1598
This lake extends about 50 miles from north to south, varies from ¼ of a mile to 2 miles in width, and is inclosed by bluffs about 250 feet high.	
Island Lake, about 125 miles east from the north end of Lake Winnipeg, estimated	900
The shores and islands of this lake abound in low outcrops of Archean rocks; but the surrounding land is for the greater part nearly level till, which "has an average elevation above the water of apparently less than 50 feet." Dr. Bell writes: "This lake is very appropriately named, being literally filled with islands in every part. The aggregate area of these islands is apparently as great as that of the water surface. The number probably amounts to several thousands."	
Wintering Lake	588
Landing Lake	624
The two foregoing are north of Sipi-wesk Lake and west of the Nelson River.	
Churchill River, 105 miles from its mouth, in the direction S. 33° W. (astr.), at the mouth of the Little Churchill River	705
Wa-kai-ow-a-ka Lake, at the head of the Little Churchill River	936
Churchill River, 23 miles above the mouth of the Little Churchill.	878
Frog portage, from the Churchill River to the Lake of the Woods, at the head of a chain of lakes and streams flowing southward to the Saskatchewan, estimated	1200
The following altitudes, from Isle à la Crosse Lake to Lake Athabasca, which are here noted as determined by Sir John Richardson (Arctic Expedition in search of Sir John Franklin), probably require an average addition of about 200 feet:	
Isle à la Crosse Lake, on the Churchill River	1300 [1500]
Thence southward to Carleton House on the North Saskatchewan, about 70 miles above the junction of the South and North Saskatchewan Rivers [estimated 1,200 feet above the sea], Richardson reports a descent of about 200 feet, across "an undulating country, but without any marked acclivity." Professor Macoun states that Isle à la Crosse, Clear, and Buffalo Lakes "are on the same level," being stagnant water filled with green scum in summer.	
Methy Lake or Lac la Loche	1490 [1690]
Same, according to Captain Lefroy, cited by Richardson	1500 [1700]
Summit of Methy portage (also called Portage la Loche and the Long Portage), on the watershed between the Churchill and Athabasca Rivers	1556 [1756]
The "Coxcomb," on this portage at the crest of the bluff descending to the Clearwater River, tributary to the Athabasca	1534 [1734]

	Feet above the sea.
Clearwater River at the north end of this portage	900 [1100]
Lake Athabasca	600 [800]
Altitudes determined by Dr. G. M. Dawson show the present height of the glacial lake bed now drained by the Peace River, and of its probable first avenues of outflow southeast to Lake Agassiz, as follows:	
Peace River at Dunvegan	1300
Top of river bluff 1 mile from Dunvegan	2100
General level of the country in this vicinity	2200
Area of lacustrine silt in the basin of the Peace River	2000–2500
The valley of this part of the river, 800 or 900 feet deep, is eroded in a vast plain, from which, according to Richardson, "the Rocky Mountains are not visible, and no range of hills meets the eye."	
Watershed between Peace River and Lesser Slave Lake	2430
Watershed between Tow-ti-now River, a tributary of the Athabasca, and the North Saskatchewan, on the trail from Athabasca Landing to Edmonton	2485

REGION OF THE CYPRESS HILLS, WOOD MOUNTAIN, AND ADJOINING COUNTRY.

[From R. G. McConnell, in the Annual Report of the Geological and Natural History Survey of Canada, for 1885. The original figures are here increased by 24 feet, because they are referred to elevations on the Canadian Pacific Railway, which, as there published, require this addition.]

	Feet above the sea.
Coteau du Missouri, east of the south end of Old Wives' Lake	2394
Same, at Secretan	2282
Same, in the Vermilion Hills, south of the South Saskatchewan River	2254
Same, in the lakelet-sprinkled plateau north of this river, in Ts. 21 to 24, Rs. 10 to 14	2000–2300
Wood Mountain	3000–3350
East part of the Cypress Hills	3800–4243
The Gap from north to south through the Cypress Hills	3744
West part of the Cypress Hills	4600–4867
Upper limit of glacial drift there, about	4400
Upper limit of glacial drift on the Hand Hills, 150 miles northwest from the foregoing (according to J. B. Tyrrell, Ann. Rep., 1886, p. 145 E), about	3200
Upper limit of drift observed by Dr. G. M. Dawson on the West Butte of the Sweet Grass Hills, nearly south of the Hand Hills, being close south of the international boundary in longitude 111° 30′	4660
[The surface of the ice-sheet thus declined here from south to north about 7 feet per mile, unless these differences in elevation of the upper limit of the drift have resulted from postglacial changes of level, which indeed appears to be the more probable explanation.]	
South Saskatchewan River, at mouth of Red Deer River	1958
Same, in T. 22, R. 18, long. 108° 27′	1782
Same, at the Elbow	1619
Old Wives' Lake (the northern lake)	2189
The northern and southern lakes, connected by a sluggish creek, have probably the same elevation.	
Many Island Lake, 25 miles ENE. of Medicine Hat	2304
Big Stick Lake, 60 miles ENE. of Medicine Hat	2278
Crane Lake, 10 miles SE. of the last	2444
Cypress Lake, at the southeast base of the Cypress Hills	3264
Twelve-Mile Lake, at the northeast base of Wood Mountain	2479
Devil's Lake, 20 miles west from the Elbow of the South Saskatchewan River	1911
(Many other elevations are also given in this report and the accompanying map.)	

REGION OF THE BOW AND BELLY RIVERS.

[From Dr. George M. Dawson in the Report of Progress of the Geological and Natural History Survey of Canada for 1882-83-84. These are from barometric observations referred to sea level by comparison with the barometric record at Fort Benton, Montana, which is assumed to have an elevation of 2,700 feet. At Lethbridge they agree, at least approximately, with the Northwest Coal and Navigation Company's Railway.]

	Feet above the sea.
Confluence of the Bow and Belly Rivers, forming the South Saskatchewan River	2212
Belly River, at the "Coal Banks," Lethbridge	2717
Old Man River, at Fort MacLeod	3096
St. Mary River, 6 miles north of the 49th parallel	3850
Waterton River, near its junction with the Upper Belly River	3217
Waterton Lake, crossed by the international boundary in long. 113° 52′, in the east edge of the Rocky Mountains	4245
Lake Pa-kow-ki, 45 miles SSW. of Medicine Hat	2735
Milk River, at Pa-kow ki Coulée, 4 miles southeast from the south end of this lake	2816
Same, at Verdigris Coulée	3065
Same, at the crossing of the trail from Fort MacLeod to Fort Benton	3546
Same, 20 miles west of this crossing	3720
North Branch of Milk River, 1 mile north of the 49th parallel, long. 113°	4173

(Many other elevations are also given in this report and the accompanying map.)

IN NORTHERN ALBERTA AND PORTIONS OF ASSINIBOIA AND SASKATCHEWAN.

[From J. B. Tyrrell in the Annual Report of the Geological and Natural History Survey of Canada for 1886. The original figures are here increased by 24 feet, because they are referred to elevations on the Canadian Pacific Railway, which, as there published, require this addition.]

	Feet above the sea.
Hand Hills	3575
Wintering Hills	3250
Medicine Lodge Hills	3500
Neutral Hills, broken ridges rising westward to the "Nose"	2500–2990
Beaver Hills	2500
Blackfoot Hills	2400
Egg Lake in T. 56, R. 16, near Victoria	2021
Birch Lake	2164
Beaver Lake	2202
Hastings Lake	2404
Cooking Lake	2424
Wavy Lake	2284
Buffalo Lake	2560
Bear Lake	2648
Pigeon Lake	2848
Battle Lake	2794
Buck Lake	2994
Gull Lake	2929
Devil's Pine Lake	2934
Quill Lakes	2885
Sullivan Lake	2644
Dowling Lake	2587
Egg Lake, in the Hand Hills	2994
Little Fish Lake	2914
Sounding Lake, at the east end of the Neutral Hills	2164
Red Deer River, at crossing of the Rocky Mountain House trail, near the mouth of Raven River	3196
Same, at the ferry on the trail from Calgary to Edmonton	2751
Same, at mouth of Tail Creek, outlet of Buffalo Lake	2414
Same, at mouth of Rosebud or Arrow-Wood Creek	2254
Same, at the Lorne crossing	2191
Battle River, at the "Leavings," on the trail from Calgary to Edmonton	2451
Same, Dried Meat Lake, 11 miles long and about ¼ mile wide, through which the river flows	2254
Same, at the Elbow, the most southern point of its course	2150
Same, at crossing of the Fort Pitt trail, southeast of the Blackfoot Hills	1718

(Many other elevations, including those of the North Saskatchewan River previously noted, are given in this report and the accompanying map.)

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Blue Mounds, Pope County	187	1,250–1,300	Mesabi Range	187	1,800–2,400
Brulé Mountain	185	2,044	Mesabi Range, near Embarras Lakes	186	1,750–1,850
Carlton's Peak (Hall)	187	1,529	Mesabi Range, south of Spotted Rock Lake	185	2,019
Carlton's Peak (Owen)	187	1,542	Minnetonka, hills surrounding lake	187	1,000
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Itasca, hills west and south of lake	148, 187	1,600–1,700	Sawteeth Mountains	187	1,300–1,700
Kiester Hills	187	1,300–1,400	South Fowl Lake, hills near	184	1,760–1,860
Langhei, highland in	187	1,350	Twin Peaks	185	1,950
Leaf Hills	187	1,400–1,750	White Earth Agency	187	1,600
Lida, hills east of lake	187	1,425			
Little Lake, hills near	185	2,000			
Lone Mound	182	1,175			

IOWA.

Mineral Ridge	187	1,200	Spirit Lake, hills near	187	1,475–1,525
Pilot Mound	187	1,425			

NORTH DAKOTA.

Bear Butte	188	2,200	St. Paul, Butte	188	2,300
Coteau du Missouri	23 74, 188, 189	1,900–2,400	Sully's Hill	188	1,707
Devil's Heart	188	1,722	Turtle Mountain (U. S. Boundary Commission)	188, 189	2,000–2,534
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MONTANA.

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			Wood Mountain, on the international boundary.	189	2, 950–3, 075

WYOMING.

Rocky Mountains, South Pass	145	7, 429

WASHINGTON.

Cascade Range, Stampede Pass, above tunnel of the Northern Pacific Railroad.	28	3, 980

ONTARIO.

Cambridge Mountain	189	1, 600	Thunder Bay, mountains west of	189	1, 600
McKay's Mountain	189	1, 824	Thunder Cape	189	1, 950

MANITOBA.

Brandon Hills	191	1, 550–1, 600	Tiger Hill, Big	191	1, 640
Duck Mountain	191	2, 300–2, 700	Tiger Hills	191	1, 500–1, 600
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SASKATCHEWAN.

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ASSINIBOIA.

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Boundary plateau	189	3,000–3,250	Cypress Hills, west part	192	4,600–4,867
Coteau du Missouri	188,189,192	2,000–2,400	Vermilion Hills	192	2,254
Cypress Hills, east part	192	3,800–4,243	Wood Mountain	189,192	3,000–3,350
Cypress Hills, the Gap	192	3,744			

ALBERTA.

Beaver Hills	193	2,500	Rocky Mountains, Wapta, or Kicking Horse Pass, grade of the Canadian Pacific Railway	47	5,323
Hand Hills	192,193	3,575			
Medicine Lodge Hills	193	3,500			
Rocky Mountains, on the international boundary	189	7,500–10,500	Wintering Hills	193	3,350

BRITISH COLUMBIA.

Gold Range, Eagle Pass, grade of the Canadian Pacific Railway	48	1,328	Selkirk Mountains, Rogers' Pass, grade of the Canadian Pacific Railway	48	4,327

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LAURENTIAN LAKES.

Erie	147	572.86	Saint Peter	147	11.00
Huron	14,147	581.28	Superior	14,18,40,59, 62,66,92,123, 124,147,184, 185,186,188, 189.	601.56
Michigan	14,147	581.28			
Ontario	147	246.61			
Saint Francis	147	151.00			
Saint Louis	147	67.00			

WISCONSIN.

Bear	159	1,433	Grindstone	159	1,288
Bear Trap	64	1,038	Hunter's	159	1,327
Big	159	1,594	Island, Courtes Oreilles River	159	1,292
Bowlder	158	1,610			
Chief	159	1,296	Island, Flambeau River	159	1,577
Chief, Little	159	1,325	Long	159	1,562
Courtes Oreilles	159	1,287	Lost	159	1,385
Crawling Stone	159	1,562	Manitouish	158	1,575
Crooked	158	1,623	Moose	159	1,362
Cross	159	1,385	Pa-kwa-wang	159	1,286
Dole	158	1,578	Partridge Crop	159	1,385
Fence	159	1,563	Pokegama, Flambeau River	159	1,562
Fish	159	1,289	Pokegama, west fork of Chippewa River	159	1,290
Flambeau	159	1,562			
Flat	159	1,320			

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WISCONSIN—continued.

	Page.	Feet above the sea.
Rest	159	1,571
Round	159	1,532
Saint Croix	60, 122, 158	672
Saint Croix, Upper	157	1,011
Sand	159	1,801
Summer	159	1,396
Trout	158	1,563
White Fish	158	1,030

MINNESOTA.

Abita	185	1,932
Addie	97	1,007
Agemok	185	1,568
Agnes	70	1,365
Albert Lea	141	1,209
Aldrich	70	1,391
Alexander	31, 160	1,275
Amelia, Anoka Co	61	906
Amelia, Pope Co	32, 162	1,347
Andrews	159	1,400
Ash	185	1,568
Aue	97	942
Badger	79	1,172
Bald Eagle	58, 183	908
Ball Club	148	1,281
Banks's Pine	184	1,385
Bass, Hennepin Co	97, 135	878
Bass, Itasca Co	149	1,279
Bass, Otter Tail Co	32	1,328
Bass, Big, Ramsey Co	60	888
Bass, Little, Itasca Co	149	1,283
Bass, Lower, Washington Co	122, 183	886
Bass, Upper, Washington Co	122, 183	900
Basswood	171, 184, 188	1,244
Battle, East and West	173	1,328
Bearskin	184	1,680
Bennett	60	893
Benton	119, 162	1,754
Big, Cook Co	186	1,647
Big Stone	98, 161	963
Birch	184	1,645
Birch Bark	31	1,177
Bow String	148, 172, 187	1,321
Bradford	136	866
Brulé, North	185	1,799
Buffalo, Becker Co	176	1,400
Burnt-side	185	1,356
Burntwood	185	1,782
Calhoun	184	852
Camp	186	1,768
Cannon	160	972
Caribou, Cook Co. (T. 64, R. 1 W.)	185	1,821
Caribou, Cook Co. (T. 65, R. 1 E.)	184	1,549
Carlos	160	1,330
Carnelian	62	873
Carp	184	1,289
Cass	148, 187	1,301
Cedar, Hennepin Co	82, 135, 184	857
Centennial	85	945
Chisago	60	896
Christina	71, 162	1,215
Chub	61	1,111
Clear, Washington Co	183	889
Clearwater, Anoka Co	183	885
Clearwater, Carver Co	85	963
Clearwater, Cook Co	184	1,661
Clitherall	32, 173	1,234
Clubfoot	185	1,756
Cokato	82	986
Como	183	885
Cormorant	176	1,340
Crane	186	1,150
Crooked, Cook Co	185	1,585
Cross, Cook Co	185	1,810
Cross, Pine Co	158	937
Cullen	149	1,196
Daniels	184	1,621
Darling	160	1,330
Dead	173	1,350
Detroit	176	1,365
Devil's Track	185, 186	1,647
Dora	136	1,042
Duck, Cook Co. (T. 63, R. 5 W.)	185	1,691
Duck, Cook Co. (T. 64, R. 2 W.)	185	1,827
Duck, Hennepin Co	97	910
East-and west	185	1,599
East Okabena	126	1,572
Elk	148	1,463
Elmo	122, 183	886
Elysian	163	1,040
Embarras	147, 186	1,415–1,320
Emily	162	1,080
Eshquagema	186	1,320
Fall	184	1,262

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	Page.	Feet above the sea.
Fanny	184	1,672
Fish Trap	31, 160	1,273
Forest	58, 183	900
Fox	185	1,509
Fowl, North	184	1,439
Fowl, South	184	1,435
Geneva, Freeborn Co	182	1,222
Glen, Hennepin Co	185	905
Gobbemichigomog	185	1,578
Goose, Chisago Co	61	910
Goose, Ramsey Co	61	925
Graham	107	1,448
Grass	160	1,125
Green	94, 160	1,154
Gull	149	1,195
Gull, Upper	149	1,200
Gunflint	171, 184, 188	1,530
Harriet	184	845
Hay, Carlton Co	61	1,105
Hay, Lower, Cass Co	149	1,227
Hazeltine	97	917
Hendricks	162	1,750
Heron	126, 161	1,406
Horn	148	1,309
Hubert	149	1,199
Hungry Jack	184, 185	1,652
Ida	159	1,400
Iron	185, 186	1,796
Island, Hennepin Co	97, 136	892
Island, Ramsey Co	64	942
Isles, Lake of the	184	852
Itasca	148, 187	1,462
Johanna, Pope Co	162	1,200
John	184	1,452
Kandiyohi	160	1,115
Kawasachong	184	1,262
Kingfisher	185	1,461
Knife	171, 184, 188	1,322
Koronis	160	1,105
L lake	185	1,756
Lac qui Parle	161	926
La Croix	171, 188	1,186
Leaf	159	1,340
Leech	80, 149	1,297
Le Homme Dieu	160	1,230
Lida	176	1,315
Lillian	160	1,110
Little Lake, north of the Misquah Hills	185	1,924
Little Lake, south of the Misquah Hills	185	1,782
Lizzie	176	1,315
Lobster	159	1,400
Long, Cass Co	149	1,200
Long, Norman Co	71, 176	901
Long, St. Louis Co	185	1,325
Long, Washington Co	63	936
Loon, Waseca Co	136	1,136
Lucy	182	954
McFarland's	184	1,453
Maple	79, 176	1,169
Maple Leaf	184	1,319
Mary	159	1,400
Mayhew	185, 186	1,796
Melissa	176	1,330
Mesabi	185	1,681
Mille Lacs	157	1,251
Miltona	159	1,400
Minnetonka	82, 85, 139, 184	927
Minnewashta	182	945
Minnewaska	32	1,135
Miranda	184	1,733
Misquah	185	1,840
Moose, Carlton Co	61	1,105
Moose, Cook Co	184	1,487
Mountain	184, 188	1,652
Mud, Carver Co	182	940
Mud, Cass Co	148	1,281
Mud, Cook Co	184	1,500
Mud, Hennepin Co	135	900
Mud, St. Louis Co	185	1,370
Namekan	171, 186, 188	1,126
Nequanquon	171, 188	1,186
Nest	94, 160	1,162
North	171, 184, 188	1,535
Ocheeda or Ocheyedan	126	1,565
Ogishkie Muncie	185	1,461
Okabena, East	126	1,572
Okabena, West	126	1,575
Osakis	70, 160	1,310
Otter, McLeod Co	85, 160	1,038
Otter Tail	173	1,315
Otter Track	171, 184, 188	1,326
Owasea	60	888
Owl	185	1,731
Pelican, Cass Co	149	1,211
Pelican, Grant Co	71, 162	1,215
Pelican, Otter Tail Co	176	1,320
Pemidji	148	1,355
Pepin	100	664
Phalen	58, 183	859
Pickerel, Freeborn Co	137	1,241
Picture	182	940

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MINNESOTA—continued.

	Page.	Feet above the sea.
Pine, Cook Co	184	1,454
Pine, Otter Tail Co	173	1,330
Pine, Pine Co	61	1,075
Pine, Ramsey Co	64	943
Pine, Little, Cook Co	185	1,737
Pleasant	183	891
Pokegama, Cass Co	149	1,275
Pokegama, Pine Co	158	937
Poplar, Cook Co	185	1,804
Portage, Cass Co	149	1,299
Portage, Cook Co	185	1,817
Prairie, St. Louis Co	186	1,385
Prior	96	907
Qui Parle, Lac	161	926
Rainy	171, 186, 188	1,117
Rat, Cook Co., T. 62, R. 5 W	185	1,802
Rat, Cook Co., T. 63, R. 1 W	184	1,506
Red	176	1,150
Red Sand	149	1,201
Reiling	60	893
Reno	162	1,400
Rice, Cook Co	186	1,737
Rice, Lower	176	1,450
Rice, Upper	176	1,500
Robinson	60	908
Rock	61	947
Rose	184	1,500
Roseau	189	1,040
Round, Cass Co	149	1,195
Round, Cook Co	185	1,791
Rove	184	1,649
Rush, Chisago Co	61	906
Rush, Otter Tail Co	173	1,320
Rush, St. Louis Co	186	1,315
Saganaga	171, 184, 185, 188	1,368
Saganaga, Little	185	1,593
St. Croix	60, 122, 158	672
Sakata	136, 160	996
Sallie	176	1,330
Sand, Otter Tail Co	71	1,187
Sand Point	186	1,145
Sandy, Aitkin Co	149	1,210
Sandy, Hennepin Co	64	838
Sandy, Ramsey Co	183	869
Shady Oak	97, 135	905
Shaokatan	162	1,750
Shell	159	1,425
Shetek	161	1,475
Smoke	186	1,754
South	184, 188	1,535
Spotted Rock	185	1,863
Squagemaw	186	1,320
Square	186	1,737
Star	173	1,350
Sturgeon (Namekan)	171, 186	1,126
Sucker, Cook Co	186	1,617
Sucker, Lake Co	184	1,288
Sunrise, Cook Co	186	1,742
Superior	14, 18, 40, 59, 62, 66, 92, 123, 124, 147, 184, 185, 186, 188, 189	601.56
Swan, McLeod Co	182	1,047
Sylvan	149	1,201
Tamarack	185	1,715
Temperance River	186	1,760
Tetonka	136, 160	996
Tiger	97	977
Tokua	99	1,091
Town Line	185	1,451
Traverse	87, 174	972
Trout, Little	185	1,855
Tulaby	176	1,500
Turtle, Otter Tail Co	32	1,327
Twin, Freeborn Co	137	1,245
Twin, Norman Co	176	1,450
Twin, Ramsey Co	60	879
Vadnais	183	881
Vermilion, Cass Co	149	1,278
Vermilion, St. Louis Co	62, 171, 185, 186	1,357
Victoria, Hennepin Co	82	89[illegible]
Villard	32, 162	1,3[illegible]
Waverly	82	[illegible]
West Okabena	126	1,[illegible]
Whipple or White Bear, Pope Co	32, 162	1,
White Bear, Ramsey Co	58, 60, 64, 183	
White Earth	176	
White Fish	149	
Wind	185	
Winnebagoshish	148	
Winnebagoshish, Little	148	
Winona, Douglas Co	70	
Winsted	182	
Woods, Lake of the	42, 171, 172, 189	
Young Sawbill	185	

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IOWA.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Medium	142	1,220	Spirit	142, 161	1,395
Okoboji	111, 142, 161	1,390			

NORTH DAKOTA.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Arrow Wood	169	1,440	Stump	73, 177, 188	1,417
Devil's	87, 73, 177	1,432	Swan	177	1,070
	158		Sweetwater	73, 188	1,468
Golden	178	1,125	Taylor	177	1,050
Jim	169	1,435			
Lac des Roches	189	1,520			

SOUTH DAKOTA.

Big Stone	98, 161	963	Lone Tree	140	1,880
Chedi	169	1,286	Madison	108	1,594
Columbia	88, 121, 169	1,286	Sand	169	1,286
Fawn	128	1,323	Tchan-chicahah	169	1,296
Hendricks	162	1,750	Traverse	87, 174	972
Herman	108	1,664	Whitewood	114	1,587
Kampeska	117, 169	1,714			

ONTARIO.

Baril	170	1,487	Kennedy	42	1,245
Basswood	171, 184, 188	1,244	Knife	171, 184, 188	1,322
Bobo	42	1,188	La Croix	171, 188	1,186
Brulé, Lower	170	1,437	Lonely	190	1,232
Brulé, Upper	170	1,440	Mc Kay's	190	1,064
Cannibals'	170	1,440	Manitowick	190	943
Clare	42	1,284	Mattagaming	190	1,025
Cold Water	170	1,881	Mille Lacs, Lac des	170, 190	1,485
Deception	42	1,094	Mountain	184, 188	1,652
Dog, Great	170, 190	1,350	Mud	42	1,328
Dog, Little	170	1,002	Muskrat	41	1,174
Dog, Michipicoten River	190	1,026	Namekan	171, 172, 186, 188	1,126
Doré	170	1,329			
Eagle	41	1,182	Nepigon	190	915
Feist	42	1,326	Nequauquon	171, 188	1,186
Fellows	42	1,235	Nipissing	190	638
French Portage	170	1,337	North	171, 184, 188	1,535
Gunflint	171, 184, 188	1,530	Otter Track	171, 184, 188	1,326
Hawk	41	1,509	Parrywood	42	1,362
Height of Land	170	1,538	Pickerel	170	1,336
Helen	42	1,138	Rainy	171, 186, 188	1,117
Kashabbiwe	190	1,494	Saganaga	171, 184, 188	1,389

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ONTARIO—continued.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Saint Joseph	191	1,172	Summit, at Summit station	42	1,384
Savanne	170	1,522	Summit, near Kalmar	42	1,252
Seul	190	1,282	Thousand Lakes	170	1,485
Shebandowan	190	1,465	Turtle	42	1,366
South (on C. P. Railway)	41	1,495	Viaduct	42	1,246
South (on international boundary)	184, 188	1,535	War Eagle	42	1,082
Stewart	41	1 303	White Fish	42	1,213
Sturgeon (Namekan)	171, 186, 188	1,126	Wooda, Lake of the	42, 171, 172, 189	1,060
Sturgeon (north of Hunters' Island)	170	1,212			

BASIN OF JAMES BAY.

Abittibi	190	857	Manitou-namaig	190	1,052
Crooked	190	1,038	Missinaibi	190	1,020
Egg	190	1,112	Mistassini	189	1,350
Fleming's	190	1,107	Mistassinis	190	1,370
Ka-wa-kash-ka-ga-ma	190	1,088	Mountain	190	1,119
Kenogami or Long	190	1,032	Muddy	190	1,064
Lansdowne	191	960	Round	190	1,052

KEEWATIN.

Cross	181	665	Sipi-wesk	181	565
Gull	181	420	Split	181	410
Island	191	900	Was-kai-ow-a-ka	191	936
Landing	191	624	Winnipeg	43, 173, 175, 181, 191	710
Pipestone	181	665			
Playgreen, Great and Little	181	710	Wintering	191	588

MANITOBA.

Bone	179	1,357	Shoal (on W. & H. B. Railway)	52	850
Bonnet	172	823	Shoal (on M. & N. W. Railway)	55	1,793
Cross	42	1,045	Swan, Pembina River	179	1,310
Dauphin	191	839	Swan, tributary to Lake Winnipegosis	191	860
Grass	179	1,355	Whitewater	50, 179	1,634
Long	43, 180	798	Winnipeg	43, 173, 175, 181, 191	710
Lorne	179	1,345	Winnipegosis	191	822
Louise	179	1,345	Wooda, Lake of the	42, 171, 172, 189	1,060
Manitoba	179, 191	809			
Pelican	179	1,355			
Rock	179	1,335			
St. Martin	191	794			
Salt	54	1,360			

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SASKATCHEWAN AND ATHABASCA.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Athabasca	192	200	Methy, or Lac la Loche	191	1,690
Buffalo	191	1,500	Playgreen, Great and Little	181	710
Cedar	181, 191	824	Sipi-weak	181	565
Clear	191	1,500	Sounding	193	2,164
Cross, Nelson River	181	665	Winnipeg	43, 173, 175	710
Cross, Saskatchewan River	181	818		181, 191	
Isle à la Crosse	191	1,500			

ASSINIBOIA.

Big Stick	192	2,278	Leech	56	1,679
Buffalo	180	1,635	Long	57, 180, 191	1,598
Crane	192	2,444	Many Island	192	2,304
Crescent	56	1,679	Old Wives'	192	2,189
Crooked	180	1,389	Pa-kow-ki	193	2,735
Cypress	192	3,261	Round	180	1,364
Devil's	192	1,911	Sand Hill	180	1,685
Eyebrow	180	1,685	Twelve-Mile	192	2,479
Fishing	180	1,504–1,500	Wild Horse	189	2,850

ALBERTA.

Battle	193	2,794	Egg, Hand Hills	193	2,994
Bear	193	2,648	Egg, near Victoria	193	2,021
Beaver	193	2,202	Gull	193	2,929
Birch	193	2,164	Hastings	193	2,404
Buck	193	2,994	Little Fish	193	2,914
Buffalo	193	2,560	Pigeon	193	2,848
Chief Mountain	189	4,245	Quill	193	2,885
Cooking	193	2,424	Sullivan	193	2,644
Devil's Pine	193	2,934	Waterton	189, 193	4,245
Dowling	193	2,567	Wavy	193	2,284
Dried Meat	193	2,254			

BRITISH COLUMBIA.

Kicking Horse	47	5,190	Summit	47	5,308

INDEX OF TOWNS AND STATIONS.

MICHIGAN.

(Minneapolis, Sault Ste. Marie and Atlantic Railway.)

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Alexander	66	815	Masonville	66	593
Cook's Mill	66	703	Menominee River	65	816
Dafter	66	695	Meyer	65	920
Delta Junction	66	667	Mille Coquins	66	632
Eustis	65	816	Naubinway	66	725
Flat Rock	65	629	Newhall	65	709
Gilchrist	66	779	Ogonts	66	620
Gladstone	65	612	Pike Lake	66	749
Gulliver Lake	66	626	Pine River	66	683
Hall's	66	864	Scott's Point	66	772
Hermansville	65	887	South Manistique	66	596
Kennedy	66	675	Springer	65	862
Leland	66	656	Sturgeon River	66	623
McDonald Lake	66	622	Trout Lake	66	836
Manistique	66	613	Van Winkle	66	592

WISCONSIN.

Amery	64	1,070	Deer Tail	65	1,221
Ames	123	1,099	Deronda	64	1,066
Armstrong Creek	65	1,427	Downsville	103	754
Ashland	123	666	Drummond	123	1,307
Ashland Junction	123	657	Dunnville	103	731
Baldwin	122	1,134	Durand	103	724
Barron	65	1,111	Eagle Point	124	974
Barronette	123	1,373	East Lincoln	64	1,100
Bayfield	123	616	Eau Claire (C., M. and St. P.)	103	788
Bear Creek	124	1,232			
Bloomer	124	1,013	Eau Claire (C., St. P., M. and O.)	122, 124	839
Boardman	123	949			
Boylston	92	687	Elk Mound	122	929
Bradley	65	1,473	Flambeau Falls	65	1,142
Bruce	65	1,098	Forest City	123	914
Burkhardt's	123	925	Gagen	65	1,645
Cable	123	1,367	Godfrey Junction	64	950
Cameron Junction	124	1,100	Gordon	124	1,024
Canton	65	1,101	Granite Lake	123	1,314
Cartwright	124	1,110	Grantsburg	61	895
Caryville	103	758	Gregory	64	1,132
Cedar Falls	103	867	Hammond	122	1,102
Central Transfer	103	900	Hawkins	65	1,365
Chandler	123	1,145	Hawthorne	124	1,154
Chapman	122	1,011	Hayward	123	1,194
Chetek	124	1,054	Hersey	122	1,199
Chicago Junction	123, 124	1,086	Hudson	122, 123	718
Clayton	123	1,203	Ingram	65	1,301
Clear Lake	123	1,197	Knapp	122	926
Comstock	123	1,232	Lake Side	124	1,108
Cumberland	123	1,241	Mason	123	965
Dedham	93	802	Maxwell	103	698
Deer Park	123	1,062	Menomonie	103	805

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WISCONSIN—continued.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Menomonie Junction	122	882	Shawtown	103	777
Meridian	103	746	Shell Lake	123	1,212
New Richmond	123	989	South Chippewa Falls	124	861
North Wisconsin Junction	122, 123	872	South Range	124	768
Nye	64	955	Spooner	123	1,095
Orme's	123	1,057	Sprague	123	1,257
Osceola	64	809	Stinnett	123	1,146
Pembine	65	968	Superior (C., St. P., M. and O.)	124	643
Pennington	65	1,635	Superior Junction	123, 124	1,089
Perley	123	1,249	Trevino	103	680
Phippe	123	1,234	Turtle Lake (C., St. P., M. and O.)	123	1,257
Pike River	65	1,222	Turtle Lake (M., S. Ste. M. and A.)	64	1,258
Pineville	123	1,249	Tyrone	103	729
Plumer's Mill	103	684	Van Horne	65	807
Porter's Mills	103	769	Veazie	123	1,084
Pratt's	123	1,027	Washburn	123	655
Prentice	65	1,551	West Eau Claire	122	880
Prescott	63	700	West Superior (C., St. P., M. and O.)	124	622
Red Cedar	103	759	West Superior (St. P., M. and M.)	92	631
Red Cedar Junction	103	729	Weyerhauser	65	1,297
Rhinelander	65	1,555	White Birch	124	1,081
Rice Lake	124	1,146	Willard	65	1,493
Richardson	123	1,197	Wilson	122	1,147
River Falls Junction	122	697	Woodville	122	1,152
Roberts	122	1,037			
Round Hill	103	736			
Rusk	122	902			
St. Croix Falls	64	920			

ILLINOIS.

(Chicago, St. Paul and Kansas City Railway.)

Aiken	131	611	Lily Lake	132	919
Byron	131	724	Lindenwood	132	774
Cairo datum plane, below mean sea-level (Mississippi River Commission)	152	—21.26	Lombard	132	721
Chicago	132	586	Maywood	132	630
Clare	132	871	Melton	131	769
Dunbar	131	853	Menominee	131	610
Elizabeth	131	785	Portage Curve	131	608
Ellis	131	821	Richardson	132	884
Esmond	132	822	St. Charles	132	728
Forest Home	132	624	South Elmhurst	132	678
Galena Junction	131	612	Stillman Valley	131	721
German Valley	131	810	Stockton	131	1,002
Gretna	132	783	Sycamore	132	842
Holcomb	132	830	Trousdale	131	638
Ingalton	132	776	Tunnel siding	131	763
Kent	131	898	Wasco	132	825
			Woodbine	131	870
			Yellow Creek	131	826

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Ada	71	906
Adams	105	1,262
Adrian	128	1,541
Afton	101	696
Airlie	107	1,644
Aitkin	20	1,206
Albany	70	1,201
Albert Lea (C., M. and St. P.)	107	1,229
Albert Lea (M. and St. L. and B., C. R. and N.)	136, 141	1,230
Alden	107	1,269
Aldrich	20	1,327
Alexandria	70	1,391
Altoona	143	1,693
Amboy, Blue Earth Co	127	1,042
Amboy, Otter Tail Co	20	1,378
Ames	83	1,065
Amiret	117	1,283
Angus	80	870
Annandale	67	1,066
Anoka	30, 69	878
Appleton (C., M. and St. P.)	98	1,007
Appleton (St. P., M. and M.)	86	1,015
Arcola	63	878
Argyle	80	845
Arlington	139	995
Armstrong, Freeborn Co.	107	1,278
Armstrong, Hennepin Co.	83	986
Ash Creek	129	1,399
Ashby	71	1,293
Atherton	89	981
Atwater	83	1,211
Auburn	96	860
Audubon	21	1,310
Augusta	97	978
Aurora	104	1,255
Austin (C., M. & St. P.)	104	1,203
Austin (C., St. P. & K. C)	133	1,197
Austin Junction	104, 105	1,200
Averill	71	917
Avoca	127	1,536
Avon	70	1,131
Bailey's (N. P.)	30	913
Bailey's (St. P., M. & M.)	70	917
Baker	89	944
Balaton	119	1,528
Bald Eagle	58, 64	928
Barden	125	741
Barnesville	71, 89	1,020
Barnum	59	1,109
Barrett	67	1,165
Barry	67	1,107
Bassett Lake	63	1,642
Batavia	99	1,163
Bath	20	1,214
Battle Lake	33	1,356
Baxter	20	1,205
Baytown	101	694
Beardsley	67	1,096
Beaver Creek	128	1,446
Becker	30, 70	972
Belgrade	67	1,278
Belle Creek	138	709
Belle Plaine	125	728
Belle Prairie	30	1,132
Bellingham	86	1,049
Beltrami	72	901
Benoit	79	1,019
Benson	83	1,049
Benton Junction	96, 97	942
Big Lake	30, 70	935
Bigelow	126	1,634
Bingham Lake	126	1,422
Birch Lake	31	1,229
Bird Island	97	1,069
Birdsall	31	1,245
Bixby	104	1,306
Blakely	125	731
Blooming Prairie	104	1,291
Bloomington	125	741
Blue Earth City	127	1,083
Bluff siding	126	1,428
Bluffton	30	1,322
Borup	71	911
Boyd	140	1,050
Brainerd	20, 30	1,209
Brandon	70	1,388
Breckenridge (N. P.)	33	962
Breckenridge (St. P., M. and M.)	33, 89	961
Breitung Mine	63	1,424
Brentwood	125	752
Brewster	126	1,488
Bridgeman	93	1,092
Bright's	102	871
Brooten	67	1,314
Browerville	78	1,282
Brown's Hill	58	975
Brown's Valley	67	969
Brownsdale	107	1,275
Brownsville	101	641

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Buffalo	67	981
Buffington	84	873
Burwell	79	914
Butterfield	126	1,187
Byron	116	1,250
Cable	80	1,012
Caledonia	108	1,179
Caledonia Junction	101, 103	639
Camden Place	66	832
Campbell	83	984
Canby	117	1,243
Cannon Falls	102, 138	816
Cannon Junction	100, 102	692
Canton	103	1,330
Carlisle	71	1,226
Carman	72, 79	877
Carver (C., M. & St. P.)	96	813
Carver (M. & St. L.)	126	722
Cascade	138	895
Castle	63	986
Castle Rock	104	936
Cazenovia	143	1,670
Cedar Lake, Aitkin Co	20	1,222
Cedar Lake, Hennepin Co	83	868
Center City	60	901
Centerville	58	933
Chanhassen	97	965
Chaska (C., M. & St. P.)	96	726
Chaska (M. & St. L.)	126	728
Chatfield	118	976
Chatfield Junction	116, 118	1,275
Chester	116	1,122
Childs	87	977
Chisago City	60	917
Chokio	87	1,124
Clara City	94	1,058
Claremont	116	1,289
Clarissa	78	1,332
Clark's Grove	183	1,322
Clarksfield	140	1,084
Claymont	58	865
Clear Lake (N. P.)	30	991
Clear Lake (St. P., M. & M.)	70	993
Clearwater	85	960
Clearwater Junction	82, 84	818
Clifton	62	961
Clinton Falls	104	1,112
Clitherall	32	1,346
Clontarf	32	1,046
Cloquet	61	1,192
Cloquet River	62	1,490
Cogel	61	1,294
Cokato	82	1,050
Cold Springs	94	1,095
Collegeville	70	1,094
Cologne	97	945
Como	69	858
Coney Island	85	971
Coon Creek	30	867
Corona	19	1,303
Correll	98	980
Cottonwood	94	1,077
Courtland	117	936
Cromwell	19	1,306
Crookston	72, 80	863
Crow Wing	30	1,194
Crystal	66	877
Curry	62	696
Cyrus	32	1,142
Dahlgren	96	980
Dakota	101	655
Dalton	71	1,359
Darling	30	1,154
Darwin	82	1,132
Dassel	82	1,089
Dawson	140	1,054
Dayton Bluff	63, 100	707
Deer Creek	32	1,396
Deerwood	30	1,277
De Forest	107	1,461
De Graff	82	1,063
Delano	82	932
Delavan	107	1,065
Delhi	139	1,022
Dellwood	60	942
Dennison	129	967
Detroit	21	1,364
Dexter	107	1,416
Dilworth	21	909
Dodge Center (C. & N. W.)	116	1,288
Dodge Center (C., St. P. & K. C.)	130	1,292
Donald Switch	103	1,354
Donaldson	80	826
Donnelly	83	1,126
Doran	83	973
Doty	118	1,310
Douglas	118	1,091
Dover	116	1,138
Dower Lake	20	1,293
Dowlan's	56	955
Downer	71	963

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Dresbach	101	674
Dubuque Junction	130, 132	1,318
Dugdale	79	1,138
Duluth	19, 59, 62, 92, 124	607
Dumont	99	1,048
Dundas (C., M. & St. P.)	104	956
Dundas (M. & St. L.)	138	928
Dundee	127	1,446
Eagle Bend	78	1,380
Eagle Lake (C. & N. W.)	116	1,012
Eagle Lake (M. & St. L.)	138	1,011
East Grand Forks	84, 72	831
East Henderson	126	737
East Minneapolis (Duluth depot)	60	833
East Minneapolis (St. P., M. & M.)	60	803
East St. Cloud	80, 70	1,025
East St. Paul	122	822
East St. Peter	126	751
East Wabasha	102	680
Easton	107	1,054
Echo	139	1,060
Eden	130	1,215
Eden Prairie	136	884
Eden Valley	67	1,123
Edgerton	107	1,565
Edgewood	127	1,022
Eggleston	100	689
Elbow Lake (M. & P.)	67	1,210
Elbow Lake (St. P., M. & M.)	78	1,197
Elgin	118	1,009
Elizabeth, east depot	78	1,240
Elizabeth, west depot	71	1,257
Elk River (N. P.)	80	893
Elk River (St. P., M. & M.)	70, 77	892
Elkton	130	1,382
Elliott	67	991
Ellsworth	143, 144	1,445
Elmer	83	912
Elmore	127	1,125
Elysian	138	1,049
Empire	129	854
Erdahl	78	1,266
Erhart's	78	1,286
Erskine	79	1,187
Estes Brook	93	1,109
Etter	100	689
Euclid	80	890
Evans	107	1,197
Evansville	71, 78	1,353
Everdell	83	994
Excelsior (St. P., M. & M.)	85	944
Excelsior (M. & St. L.)	139	947
Eyota	116	1,237
Fair Ground, Faribault	138	978
Fairfax	139	1,041
Fairfield	96	941
Fairmont	107	1,188
Faribault (C., M. & St. P.)	104	1,008
Faribault (M. & St. L.)	138	973
Farmington	96, 104	905
Farwell	67	1,339
Felton	71	915
Fergus Falls (N. P.)	83	1,185
Fergus Falls (St. P., M. & M.)	71, 78	1,210
Fertile	84	1,140
Finkle	83	912
Finlayson	59	1,108
Fisher	72	852
Florence	94	1,725
Foley	93	1,132
Fond du Lac	19	607
Forest Lake	58	912
Forest Mills (C., M. & St. P.)	102	969
Forest Mills (C. & N. W.)	118	1,023
Fort Ripley	80	1,169
Fort Snelling	96	722
Fosston	80	1,288
Fountain	106	1,304
Four Lakes	63	966
Foxboro	93	956
Franconia	60	915
Franklin	139	1,005
Frazee	21	1,389
Freeburg	103	659
Freeport	70	1,240
French	83	1,087
Fridley (N. P.)	29	847
Fridley (St. P., M. & M.)	60	844
Frontenac	100	718
Fulda	107	1,522
Funk	103	819
Gakadina	62	1,734
Garden City	127	961
Garden Place	64	932
Garfield	70	1,417
Gaylord	139	993
Georgetown	89	884

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Gladstone	58	898
Glasgow	102	715
Glencoe	97	1,006
Glenville	141	1,235
Glenwood (M. & P.)	67	1,390
Glenwood (N. P.)	32	1,403
Glyndon	21, 71	925
Good Thunder	108	982
Gorton	83	1,024
Graceville (C., M. & St. P.)	99	1,111
Graceville (St. P., M. & M.)	87	1,109
Grand Meadow	107	1,340
Grand View	117	1,173
Granite Falls (C., M. & St. P.)	98	941
Granite Falls (St. P., M. & M.)	94	930
Granville	138	895
Gray Eagle	81	1,225
Greeley	19	838
Green Isle	139	1,001
Green Valley	94	1,105
Gregory	80	1,100
Ground House	93	1,040
Grove City	82	1,192
Gull River	20	1,191
Hadley	127	1,692
Hallock	80	815
Halstad	89	870
Hamburg	139	1,000
Hamel	66	986
Hamilton	125	718
Hamline	29, 69	926
Hammond	102	804
Hampton	129	980
Hancock	82	1,157
Hanley Falls (M. & St. L.)	139	1,047
Hanley Falls (St. P., M. & M.)	94	1,049
Hansen	81	1,270
Harmony	103	1,339
Harris	58	897
Hartland	136	1,251
Hassan	84	913
Hastings	96, 100	707
Hatfield	107	1,677
Havana	116	1,246
Haven	70	1,014
Hawick	94	1,238
Hawley	21	1,151
Hayden	20	1,255
Hayfield	130, 132	1,315
Hayward	107	1,256
Hazel Run	140	1,057
Hazeltine	97	928
Hector	97	1,081
Helena	136	888
Hendrum	89	875
Henning	32	1,439
Hereford	78	1,078
Herman	83	1,072
Heron Lake	126, 127	1,420
Hersey	126	1,488
Hillsdale	21	1,197
Hinckley	59, 93	1,032
Hobart	21	1,386
Hoffman	67	1,246
Hokah	106	651
Holland	94	1,780
Holy Cross	88	921
Holyoke	93	1,141
Homer	101	661
Hopkins (C., M. & St. P.)	97	911
Hopkins (M. & St. L.)	135, 139	921
Hotel St. Louis	139	943
Houston	106	681
Howard Lake	82	1,010
Humboldt	80	792
Hutchinson	85	1,040
Hutchinson Junction	82, 85	903
Iceland	125	1,001
Ihlen	94	1,618
Interlaken	71	1,230
Inver Grove	129	718
Iona	107	1,623
Iosco	136	1,148
Isinour's	106	901
Itasca (N. P.)	30	885
Itasca (St. P., M. & M.)	70	837
Ives	81	986
Janesville	116	1,063
Jarrett	102	791
Jasper	95	1,545
Johnson, Becker Co	21	1,391
Johnson, Big Stone Co	87	1,129
Jonesville	20	1,238
Jordan (C., St. P., M. & O.)	125	753
Jordan (M. & St. L.)	136	755
Kanaranzi	143	1,505
Kandiyohi	82	1,223
Kasota	117, 125	804
Kasson	116	1,252

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Keegan	102	758
Kellogg	101	701
Kennedy	80	825
Kensington	67	1,318
Kent	83	942
Kenyon	129	1,140
Kerkhoven	82	1,110
Kerrick	93	1,155
Kettle River	59	1,031
Keystone	34	855
Kilkenny	136	1,058
Kimball Prairie	67	1,138
Kimberly	19	1,237
Kinbrae	107	1,461
Kittson	72	885
Knife Falls	61	1,192
Knife River	62	620
Kragnes	89	892
La Crescent	101, 106	649
La Fond	31	1,186
Lake Benton	119	1,759
Lake Crystal	125, 127	997
Lake City	100	703
Lake Elmo	122	933
Lake Park	21	1,336
Lake View	62	661
Lake Wilson	127	1,659
Lakefield	107	1,475
Lakeland	101	742
Lakeland Junction	122	706
Lakeville	96	941
Lakey	102	755
Lamberton	117	1,144
Lamoille	101	658
Lanesboro	106	843
Langdon	100	811
Lansing	104	1,229
Lawndale	71	1,089
Lena	118	1,073
Lenox	30	1,176
Le Roy	105	1,286
Le Sueur	125	750
Lester Park	62	650
Lester Prairie	85	982
Lewiston	116	1,211
Lincoln, Morrison County	31	1,281
Lincoln, Watonwan Co	125	1,045
Lindstrom	60	932
Lintonville	67	1,220
Litchfield	82	1,129
Little Falls	30, 31	1,117
Little Sauk	77	1,253
Lockhart	72	893
Long Lake	82	954
Long Prairie	78	1,299
Long's Spur	58	943
Loretto	66	995
Louisburg	86	1,042
Lowry	67	1,368
Luce	21	1,373
Luverne (B., C. R. & N.)	143	1,452
Luverne (C., St. P., M. & O.)	128, 129	1,454
Lyle (C., M. & St. P.)	105	1,206
Lyle (C., St. P. & K. C.)	133	1,202
Lynd	94	1,330
Mabel	103	1,117
McCracken	102	731
McGregor	19	1,228
McIntosh	79	1,218
Madelia	125	1,024
Madison, Lac qui Parle County	140	1,095
Madison, Mower County	104	1,255
Madison Lake	138	1,049
Magnolia	128	1,519
Mahtomedi	60	929
Mahtowa	59	1,147
Mallory	72	837
Manchester	136	1,264
Mankato (C., M. & St. P. & M. & St. L.)	108, 135	778
Mankato (C. & N. W.)	117	781
Mankato (C., St. P., M. & O.)	125	794
Mankato Junction	116	806
Manomin	69	844
Mansfield	93	1,156
Manston	89	978
Maple Grove	84	943
Maple Island	64	961
Maple Lake	67	1,052
Maple Plain	82	1,023
Mapleton	108	1,039
Maplewood	52	1,362
Marietta	140	1,128
Marine	64	927
Marmion	66	918
Marshall (C. & N. W.)	117	1,174
Marshall (St. P., M. & M.)	94	1,169
Maryland Park	64	926
Mayer	85	955
Maynard	94	1,030
Mazeppa	103	894

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Mendota Junction (C., M. & St. P.)	96	722
Mendota Junction (C., St. P., M. & O.)	125	717
Mentor	79	1,167
Meriden	116	1,149
Merriam Junction	125, 126	755
Merriam Park	95	908
Mesaba Heights	62	1,604
Midland Junction	101, 102	694
Midvale	122	1,007
Milaca	77, 98	1,072
Milaca Junction	77, 98	1,070
Milan	98	995
Milford	117	994
Mill Park	32	1,225
Miller	59	1,186
Millville	102	786
Minneapolis (C., M. & St. P.)	95, 96, 97, 100, 104, 183	826
Minneapolis (St. P., M. & M., union depot)	29 60, 63, 64, 66, 69, 82, 84, 1 3 5, 183	810
Minneapolis, zero of city levels	183	796. 64
Minnehaha	96	813
Minneiska	101	670
Minneopa	125	874
Minneota	117	1,179
Minnesota City (C., M. & St. P.)	101	675
Minnesota City (C. & N. W.)	116	676
Minnesota Falls	98	1,041
Minnesota Lake	108	1,046
Minnetonka Mills	139	996
Mission Creek	58	995
Money Creek	106	701
Montevideo	98	927
Monticello	84	933
Montgomery	126	1,065
Montrose	82	994
Moorhead (N. P.)	21	905
Moorhead (St. P., M. & M.)	88, 89	904
Moose Island	83	1,087
Moose Lake	59	1,063
Morgan	118	1,050
Morris (N. P.)	32	1,129
Morris (St. P., M. & M.)	83	1,131
Morristown	138	1,010
Morton	139	841
Motley	20	1,227
Mound Prairie	106	662
Mount Vernon	101	678
Mountain Lake	126	1,303
Mulford's	136	1,062
Muskoda	21	1,090
Myers	98	932
Nash	67	1,000
Nassau	86	1,122
Nelson	70	1,369
Nerstrand	129	1,182
New Brighton	64	920
New House	103	1,194
New London, Kandiyohi County	94	1,215
New London, Saint Louis County	62	685
New Prague	136	975
New Richland	136	1,180
New Ulm	117	837
New York Mills	20	1,410
Newport (C., B. & N.)	63	748
Newport (C., M. & St. P.)	100	749
Nicollet	117	980
Nicols	125	717
Norcross	83	1,041
Norman, Carlton County	19	1,317
Norman, Norman County	34	1,099
North Branch	58	896
North Redwood	139	855
Northcote	80	802
Northern Pacific Junction	19, 59, 61	1,083
Northfield (C., M. & St. P.)	102, 104	916
Northfield (M. & St. L.)	138	912
Norwood (C., M. & St. P.)	97	988
Norwood (M. & St. L.)	139	977
Oak Park	93	1,130
Oakdale	122	979
Oakes	70	1,240
Oakland	107	1,273
O'Brien	93	1,078
Odessa	98	963
Okabena	107	1,422
Okwanim	62	1,494
Olivia	97	1,082
Olmsted	110	1,054

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Oronoco	118	1,041
Ortonville	98	990
Osakis	70	1,343
Oshawa	117	982
Osseo	84	888
Otisco	136	1,148
Otisville	64	788
Ottawa	125	793
Otter Creek	59	1,150
Owatonna (C., M. & St. P.)	104	1,146
Owatonna (C. & N. W.)	116	1,144
Owassa	60	927
Palmer	136	1,148
Parent	93	1,120
Park Junction	139	938
Parkdale	71	1,276
Parker	84	880
Parkton	82	1,396
Partridge	93	1,166
Paxton	118	1,039
Paynesville (M. & P)	67	1,172
Paynesville (St. P., M. & M.)	94	1,180
Pelican Junction	32, 78	1,189
Pelican Rapids	78	1,304
Pennock	82	1,123
Perham	20	1,370
Perley	89	877
Peterson	106	758
Pillager	20	1,203
Pine City	58	952
Pine Grove	19	1,237
Pine Island	118	998
Pipestone (B., C. R. & N.)	143	1,725
Pipestone (C., M. & St. P.)	107	1,728
Pipestone (C., St. P., M. & O.)	127	1,723
Pipestone (St. P., M. & M.)	94	1,729
Plainview	118	1,167
Plainview Junction	116, 118	1,275
Pleasant Grove	182	1,310
Point Douglas	63, 101	708
Pokegama	93	1,028
Post's	122	847
Prairie Junction	107, 126	1,429
Pratt	104	1,223
Preston	103	922
Princeton	77	974
Prior Lake	96	947
Ramsey	104, 107	1,221
Randall	80	1,178
Randolph	102, 129	876
Rapidan	108	987
Raymond	94	1,084
Read's Junction	100, 103	686
Read's Landing	100	681
Red Lake Falls	34	1,635
Red Rock	132	1,256
Red Wing (C., M. & St. P.)	100, 102	685
Red Wing (M. & St. L.)	138	708
Red Wing, zero of city levels	100	668
Redwood	119	1,631
Redwood Falls	118	1,033
Redwood Junction	117, 118	1,015
Relf	80	1,265
Renova	130	1,387
Renville	98	1,064
Rice's	80	1,062
Rice's Point	124	617
Rich Valley	129	860
Richland	20	1,396
Richmond, Stearns Co	94	1,122
Richmond, Winona Co	101	672
River Junction	101	642
Rochester	116	991
Rockville	93	1,075
Rolette	72	892
Roscoe	94	1,161
Rose Creek	104	1,251
Rosemount	104	960
Rossburg	20	1,222
Rothsay	71	1,190
Round Lake	144	1,553
Royalton	80	1,080
Rupert	99	1,136
Rush City	58, 61	917
Rushford	106	724
Rushmore	128	1,668
Russell	94	1,518
Russia	72	892
Ruthven	94	1,733
Sabin	89	930
Sacred Heart	98	1,061
St. Albans	82	927
St. Anthony Park (N. P.)	29	904
St. Anthony Park (St. P., M. & M.)	69	878
St. Augusta	85	1,014

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	Page.	Feet above the sea.
St. Charles	116	1,139
St. Cloud	70, 85, 93	1,037
St. Cloud Junction	70, 93	1,048
St. Croix Junction (C., B. and N.)	63	692
St. Croix Junction (C., M. and St. P.)	100, 101	994
St. Francis	93	1,115
St. Hilaire	81	1,086
St. James	126	1,076
St. John's	83	1,123
St. Joseph	70	1,088
St. Lawrence	125	748
St. Louis River	62	1,607
St. Michael's	84	959
St. Paul	15, 29, 58, 63, 68, 69, 82, 95, 96, 100, 122, 125, 129, 133	703
St. Paul, zero of city levels	133	692.60
St. Paul Junction	96, 104	760
St. Peter	117	812
St. Peter Junction	101	674
St. Vincent	80	787
Sanborn	117	1,089
Sandstone Junction	59	1,119
Sargent	130	1,380
Sauk Center (N. P.)	31	1,244
Sauk Center (St. P., M. and M.)	70, 77	1,255
Sauk Rapids	30	1,005
Sawyer	19	1,317
Shafer's	60	937
Shakopee (C., M. & St. P.)	96	753
Shakopee (C., St. P., M. & O.)	125	745
Shelbyville	127	1,055
Sherburne	107	1,285
Shirley	80, 81	900
Short Line Junction	95, 96, 97	842
Sibiwissa	62	1,230
Sicottes	19	1,271
Silver Creek	84	1,013
Silver Lake	85	1,052
Sioux Falls Junction	126, 128	1,637
Skyberg	130	1,194
Slayton	127	1,608
Sleepy Eye	117	1,034
Smith Lake	82	1,054
South Bend	125	811
South Euclid	84	901
South Haven	67	1,102
South Stillwater	101	694
Spaulding	31	1,294
Spicer	94	1,167
Spirit Lake	19	610
Spooner's Spur	58	917
Spring Grove	103	1,324
Spring Valley	106	1,268
Springfield	117	1,025
Stacy	58	896
Staffordsville	66	927
Stanton	129	920
Staples's Mills	20, 31	1,274
Starbuck	32	1,161
Stephen	80	827
Stewart	97	1,064
Stillwater (C., M. & St. P.)	101	694
Stillwater (St. P. & D.)	60	723
Stillwater, zero of city levels.	60	638.70
Stillwater Junction	122	879
Stockton	116	753
Stockwood	21	948
Sturgeon Lake	59	1,072
Summit, Carver Co	136	876
Summit, Carlton Co	59	1,115
Sumter	97	1,035
Swanville	31	1,173
Swede Grove	32	1,192
Sylvan Lake	20	1,207
Tamarack	19	1,271
Taopi	105, 130	1,342
Taylor's Falls	60	791
Tenny, Clay Co	21	922
Tenney, Wilkin Co	67	990
Theilman	102	742
Thomson (N. P.)	19	1,032
Thomson (St. P. & D.)	59	1,055
Thorsborg	78	1,206
Thorson	67	1,334
Tilden	34	1,116
Tintah	78, 83	997
Tintah Junction	83, 87	988
Topeka	30	1,143
Tower	62	1,400
Tracy	117, 119	1,403
Trosky	143	1,702
Twin Lakes	137	1,261
Twin Valley	34	1,093
Two Harbors	62	634
Two Harbors Junction	62	692
Tyler	119	1,750

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	Page.	Feet above the sea.
Ulen	34	1,154
Underwood	32	1,345
Utica	116	1,170
Vadnais Park	64	898
Varco	133	1,205
Verdi	119	1,771
Vermillion	96	825
Verndale	20	1,349
Vernon Center	127	1,022
Victoria	139	965
Villard	32	1,360
Vining	32	1,391
Viola	118	1,129
Wabasha	100, 102, 103	711
Waconia	139	986
Waconta	100	706
Wadena	20	1,350
Wadena Junction	20, 32	1,252
Wall Lake	32	1,292
Walnut Grove	117	1,223
Waltham	132	1,325
Wareham	93	1,082
Warner	128	1,465
Warren	80	853
Warrendale	29	925
Warsaw	138	1,009
Waseca	116, 136	1,153
Watab	30	1,053
Waterford (C., M. & St. P.)	102	902
Waterford (M. & St. L.)	138	905
Waterville	136, 138	1,010
Watkins	67	1,162
Watosco	33	980
Watson	98	1,029
Waverly	82	999
Wayzata	82	936
Weaver	101	672
Welch	102	719
Wells	107	1,161
Wendell	67	1,148
West Concord	130	1,232
West St. Paul	129	702
West Union	70	1,337
Westcott	104	883
Westport	31	1,334
Whalan	106	788
Wheaton	99	1,018
Wheeler	87	1,112
Wheelock	20	1,214
White Bear	58, 60	938
Whitman	101	678
Wilder	126	1,451
Willmar	82, 94	1,131
Willmar Junction	82, 94	1,133
Willow River	59	1,038
Wilson	64	933
Windom	126	1,356
Winnebago City (C., M. & St. P.)	107	1,104
Winnebago City (C., St. P., M. & O.)	127	1,005
Winnipeg Junction	21, 34	1,181
Winona (C., M. & St. P.)	101	660
Winona (C. & N. W.)	116	668
Winthrop	139	1,016
Wissakode	62	1,578
Withrow	64	980
Wolverton	83	929
Wood Lake	139	1,059
Woodstock	127	1,825
Worthington	126, 144	1,585
Wright	19	1,309
Wykoff	106	1,312
Wyoming	58, 60	960
Young America	139	993
Zumbro Falls	102	835
Zumbrota (C., M. & St. P.)	102	979
Zumbrota (C. & N. W.)	118	971
Zumbrota Junction	116, 118	999

IOWA.

Abbott	142	1,099
Afton Junction	134	1,162
Akron	112	1,155
Algona	110	1,194
Almoral	131	978
Altavista	130	1,155
Alton	126	1,305
Ariapo	134	1,268
Ashton	126	1,445
Aurora	131	1,135
Austin	112	1,204
Bailey	130	1,282
Bard	140	500
Barney	134	1,047
Baxter	134	998
Belmond	144	1,184

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	Page.	Feet above the sea.		Page.	Feet above the sea.
Beloit	112	1,240	Elgin	142	843
Benson's Grove	137	1,222	Elma	130	1,182
Benton	134	1,051	Elmira	141	751
Berlin	133	1,056	Ely	141	741
Berwick	134	845	Emmetsburg (B., C. R. & N.)	142	1,234
Blockton	135	1,074	Emmettsburg (C., M. & St. P.)	110, 111	1,237
Bode	142	1,150	Estherville (B., C. R. & N.)	143	1,284
Bonair	105	1,309	Estherville (C., M. & St. P.)	111	1,208
Bondurant	134	963	Fairbank	133	1,060
Boyd	130	1,128	Farley	131	1,068
Boyden	110	1,423	Forest City	137	1,226
Brainard	142	919	Fort Atkinson	109	1,011
Britt (C., M. & St. P.)	110	1,235	Fort Dodge (Ill. Cl.)	137	1,032
Britt (M. & St. L.)	137	1,236	Fort Dodge (M. & St. L. and D. M. & F. D.)	137	1,015
Burlington	140	533	Fort Dodge (M. & St. L., upper depot)	137	1,126
Calliope	112	1,182	Fredericksburg	130	1,075
Calmar	105, 109	1,257	Galtville	142	1,198
Carleton	142	1,150	Garner	110, 144	1,209
Carpenter	105	1,190	Garrison	142	859
Castalia (B., C. R. & N.)	142	1,240	Gladbrook	133	949
Castalia (C., M. & St. P.)	109	1,245	Goldfield	142	1,108
Cedar Falls	141	854	Goodell	144	1,236
Cedar Rapids	141	732	Graf	131	768
Center Point	141	819	Grafton	105	1,228
Centerdale	141	725	Granite	141	1,407
Charles City	109	1,005	Green Mountain	133	994
Chester	105	1,232	Greene	141	924
Chickasaw	109	1,141	Grundy Center	142	976
Clarion	142	1,168	Hanley	134	883
Clarksville	141	924	Hardy	142	1,129
Clear Lake	110	1,238	Harper's Ferry	101	646
Clermont	142	866	Hartley	110	1,458
Cleves	142	1,070	Hawarden	121	1,181
Columbus Junction	140	595	Hazleton	142	998
Cone	141	618	Heytman's	101	634
Conover	105, 106	1,235	High Lake	111	1,266
Corwith	137	1,186	Holland	142	995
Cresco	105	1,300	Hospers	126	1,341
Decorah (B., C. R. & N.)	142	863	Hudson	133	883
Decorah (C., M. & St. P.)	106	875	Hull	110	1,433
Devon	130	1,194	Humboldt	137	1,095
Dewar	133	889	Independence	141	921
Doon	129	1,285	Inwood	110	1,471
Dow's	142, 144	1,142	Iowa Falls	142	1,107
Dubuque	131	611	Ira	134	826
Dundee	131	1,001	Kidder	131	860
Dunkerton	133	945	Knowlton	134	1,093
Durango	131	643			
Dyersville	131	945			
Dysart	142	968			
East Orange	126	1,305			
East Waterloo	133	843			

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	Page.	Feet above the sea.
Lake Mills	137	1,270
Lake Park	143, 144	1,479
Lamont	131	1,045
Lansing	101	632
La Porte	141	812
Larchwood	144	1,462
Latty	140	733
Leland	137	1,222
Le Mars	126	1,224
Lida	134	848
Lime Springs	105	1,246
Linn Junction	141	756
Linton	140	771
Livermore (B., C. R. & N.)	142	1,136
Livermore (M. & St. L.)	137	1,141
Lorimor	134	1,224
Lowther	130	1,208
Luana	109	1,120
Luray	134	934
Madison	137, 144	1,214
Maloy	135	1,116
Manly Junction	141	1,201
Marble Rock	141	1,002
Marshalltown	134	895
Mason City	105, 110	1,128
Maynard	142	1,106
Mediapolis	140	779
Melbourne	134	1,040
Millman	134	830
Mingo	134	819
Missouri Valley	145	1,002
Monette	134	1,227
Monona	109	1,209
Morning Sun	140	745
Morrison	142	947
Morse	141	763
Mount Auburn	141	863
New Albin	101	648
New Hampton (C., M. & St. P.)	109	1,154
New Hampton (C., St. P. & K. C.)	130	1,150
Nichols	141	638
Nora Junction	141	1,062
Nordness	142	1,085
Norman	137	1,285
Norris	141	864
North McGregor	101, 109	625
Northwood	141	1,222
Oasis	141	800
Ocheyedan	143	1,551
Oelwein (B., C. R. & N.)	142	1,049
Oelwein (C., St. P. & K. C.)	130, 133	1,036
Oneida	131	1,045
Ossian (B., C. R. & N.)	142	1,271
Ossian (C., M. & St. P.	109	1,269
Otranto	105	1,170
Palo	141	751
Peru	134	939
Pleasant Ridge	134	965
Plymouth	105	1,125
Plymouth Junction	105, 141	1,126
Port Allen	141	612
Postville (B., C. R. & N)	142	1,102
Postville (C., M. & St. P.)	109	1,195
Postville Junction	142	1,062
Randalia	142	1,106
Redhead	134	805
Reinbeck (B., C. R. & N.)	142	926
Reinbeck (C., St. P. & K. C.)	133	923
Riceville	130	1,229
Robertson	142	1,175
Rock Falls	141	1,104
Rock Rapids (B., C. R. & N.)	144	1,345
Rock Rapids (C., St. P., M. & O.)	129	1,317
Rock Valley	110	1,253
Rockford	141	1,021
Rockton	133	874
Rodman	142	1,193
Rowan	144	1,205
Rowley	141	990
Ruthven	110	1,434
St. Gilman	126	1,445
Sanborn	110	1,552
Santiago	134	832
Seney	126	1,224
Shannon City	134	1,139
Sheldon (C., M. & St. P.)	110	1,415
Sheldon (C., St. P., M. & O.)	126	1,409
Shellrock	141	921
Shellsburg	141	774
Sibley (B., C. R. & N.)	143	1,502
Sibley (C., St. P., M. & O.)	126	1,512
Sioux City (C., M. & St. P.)	112	1,104
Solon	141	794
South Des Moines	134	795
Spencer	110, 111	1,319

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	Page.	Feet above the sea.		Page.	Feet above the sea.
Sperry	140	757	Wapello	140	588
Spirit Lake (B., C. R. & N.)	143	1,457	Washburn	141	827
Spirit Lake (C., M. & St. P.)	111	1,458	Waterloo	141	841
Stanley	131	1,098	Waukon Junction	101	631
State Line	141	1,232	Wells	142	1,058
Sumner	130	1,060	Wesley	110	1,257
Sylvan	134	842	West Bend	142	1,197
Talmage	134	1,072	West Branch	141	718
Thorpe	131	1,047	West Liberty	141	673
Toddville	141	780	West Union	142	1,115
Traer	142	915	West Waterloo	133	845
Valaria	134	818	Westfield	112	1,131
Vinton	141, 142	810	Westgate	130	1,091
Walker	141	800	Whittemore	110	1,206
			Wilson's Junction	133	870
			Winslow	141	884

MISSOURI.

(Chicago, St. Paul and Kansas City Railway.)

Cawood	135	935	St. Joseph	135	820
Conception	135	982	St. Louis directrix (zero of city levels), datum of leveling by the Missouri River Commission	168	412.71
Dean	135	882			
Guilford	135	941			
Iona	135	1,063	Savannah	135	1,085
Parnell City	135	1,023	Sheridan	135	1,037
Ravenwood	135	1,015			
Rea	135	1,064			

NORTH DAKOTA.

Abercrombie	99	935	Babcock	68	1,324
Absaraka	92	1,080	Barlow	87	1,545
Addison	90	917	Barney	83	1,033
Adrian	36	1,355	Barrett	90	953
Alicia	68	1,157	Bartlett	73	1,529
Almont	23	1,920	Barton	81	1,505
Alta	22	1,427	Bathgate	84	821
Alton	83	898	Beach	24	2,756
Amenia	90	954	Bean's	34	893
Andrews	24	2,478	Belfield	24	2,579
Antelope	23	2,411	Belle Plaine	88	1,270
Apple Creek	23	1,644	Berlin	86	1,470
Ardock	84	824	Berthold	74	2,082
Argusville	83	884	Berwick	74	1,482
Arthur	90	992	Bisbee	81	1,600
Arvilla	72	1,017	Bismarck	23	1,670
Auburn	84	842	Blanchard	90	947
Avoca	74	1,956	Bloom	22	1 486
Ayr	92	1,200	Blue Grass	23	2,041

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	Page.	Feet above the sea.		Page.	Feet above the sea.
Bottineau	81	1,638	Edgeley (N. P.)	36	1,568
Bowesmont	35	791	Edinburgh	91	1,189
Boynton	68	1,497	Edmunds	87	1,597
Brampton	114	1,291	Eland	24	2,436
Brookland	88	1,304	Eldridge	22	1,541
Buchanan	37	1,548	Elgin	92	1,200
Buffalo	22	1,202	Ellendale (C., M. & St. P.)	115	1,449
Buford	75	1,944	Ellendale (St. P., M. & M.)	89	1,453
Buttsville	35	1,173	Elliott	36	1,310
Buxton	83	930	Elton	74	2,195
Cando	81	1,488	Emerado	72	898
Canfield	21	905	Erie	91	1,126
Carrington	37	1,584	Everest	90, 91	935
Cashel	35	804	Fairmount (C., M. & St. P.)	99	983
Casselton (N. P.)	22	934	Fairmount (M. & P.)	67	985
Casselton (St. P., M. & M.)	90	938	Fairview	33	967
Cayuga	87	1,140	Fargo (C., M. & St. P.)	99	903
Christine	99	928	Fargo (N. P.)	21	905
Church's Ferry	73, 81	1,458	Fargo (St. P., M. & M.)	33	902
Clement	68	1,394	Farmington	33	962
Cleveland	22	1,842	Forest River	34	862
Clifford	92	1,055	Forman	68	1,251
Cold Spring	23	1,964	Fort Totten Station	37	1,566
Colfax	90	960	Fryburg	24	2,708
Colgate	92	1,177	Fullerton	68	1,442
Conway	90	988	Galesburg	92	1,079
Cooperstown	37	1,428	Gardner	33	886
Cotter's	35	911	Geneseo	37	1,164
Crescent Hill	88	1,313	Geneva	23	1,835
Crystal Springs	22	1,792	Gilby	34	879
Cummings	33	928	Gladstone	23	2,348
Curlew	23	1,956	Glasston	34	836
Dalrymple	22	922	Glenullen	23	2,070
Davenport	35, 90	923	Glover	36	1,373
Dawson	22	1,748	Grafton (N. P.)	35	824
Dasey	37	1,433	Grafton (St. P., M. & M.)	34	827
De Lamere	33	1,066	Grand Forks (N. P.)	34	834
De Villo	37	987	Grand Forks (St. P., M. & M.)	72, 84	830
Delta	74	2,258	Grand Forks Junction	72, 84	836
Denbigh	74	1,485	Grand Harbor	73	1,454
Des Lacs	74	1,897	Grandin	33	891
Devil's Lake	73	1,464	Grand Rapids	36	1,321
Dickey	36	1,360	Granville	74	1,503
Dickinson	24	2,405	Greene	22	916
Drayton	35	798	Greenfield	90	948
Driscoll	23	1,871	Guelph	39	1,369
Duane	115	1,478	Haggart	21	905
Durbin	90	918	Hamilton	34	824
Dwight	90	954	Hankinson (M. & P.)	68	1,070
Eagle's Nest	23	2,098			
Eckelson	22	1,445			
Edgeley (C., M. & St. P.)	115	1,556			

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	Page.	Feet above the sea.
Hankinson (St. P., M. & M.)	87	1,068
Hannaford	87	1,382
Harlem	114	1,323
Harwood	83	886
Hatton	90	1,085
Havana	88	1,294
Hebron	23	2,158
Hickson	99	917
Hillsboro	83	901
Hobart	22	1,419
Hope	92	1,241
Horace	35	919
Hunter	90	980
Inkster	90	1,036
Jamestown	22, 36	1,408
Johnstown	34	871
Joliette	35	794
Kelley's	34	842
Kelso	83	897
Kempton	90	1,127
Kindred	90	942
Knife River	23	2,188
Knox	74	1,605
Kurtz	23	2,025
Lakota	73	1,514
La Moure	36	1,307
Langdon	91	1,610
Larimore	73, 90	1,134
Leeds	73	1,514
Lehigh	83	957
Leonard	35	1,047
Levant	34	822
Lidgerwood (M. & P.)	68	1,092
Lidgerwood (St. P., M. & M.)	87	1,122
Lisbon	36	1,091
Little Missouri	24	2,266
Lone Tree	74	1,995
Ludden	121	1,303
McCanna	90	1,140
McKenzie	23	1,698
Magnolia	22	1,077
Mandan	23	1,646
Manitou	74	2,275
Manvel	34	819
Mapes	73	1,526
Mapleton	21	907
Marmot	23	1,731
Marshall	36	1,343
Mayville	90	978
Mckinock	34	861
Medbery	36	1,522
Medina	22	1,704
Medora	24	2,267
Melville	37	1,603
Menoken	23	1,720
Michigan City	73	1,517
Milnor	33	1,097
Milton	91	1,586
Minnewaukan	37	1,461
Minot	74	1,557
Minto	84	820
Monango	115	1,503
Montpelier	36	1,358
Mooreton	33	969
Murray	90	960
Neche	84	831
New Rockford	37	1,531
New Salem	23	2,163
Niagara	73	1,440
Nicholson	68	1,309
Northwood	90	1,119
Norwich	74	1,526
Oakes (C. & N. W., and N. P.)	36, 121	1,313
Oakes (M. & P.)	68	1,322
Oberon	37	1,559
Odell	37	1,426
Ojata	72	858
Oriska	22	1,270
Orr's	90	1,098
Osnabrock	91	1,620
Oswald	68	989
Page City	92	1,175
Park River	90	998
Park River Junction	73, 90	1,133
Parkhurst	37	1,502
Pembina	35	789
Perry	68	1,205
Perth	81	1,731
Petersburg	73	1,519
Pingree	37	1,550
Pleasant Lake	74	1,603
Portland	92	983
Portland Junction	90, 92	1,009
Ransom	68	1,131
Ray	74	2,271
Reynolds	34	910
Richardton	23	2,466
Ripon	91	1,040
Riverdale	88	1,304
Rolla	81	1,818
Roseville	92	1,009
Ross, Foster Co.	37	1,591
Ross, Mountraille Co	74	2,251

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Rugby Junction	74, 81	1,561	Tappen	22	1,762
Rutland	88	1,225	Taylor	23	2,488
St. John	81	1,945	Thompson	84	865
St. Thomas	84	840	Tioga	74	2,273
Sanborn	22, 37	1,444	Towanda	68	1,318
Sargent	114	1,303	Tower City	22	1,172
Saunders	99	907	Towner	74	1,475
Schurmeier	84	826	Trenton	75	1,894
Scoria	24	2,462	Tyler	99	969
Sedalia	23	2,032	University	72, 84	833
Sentinel Butte	24	2,709	Urbana	22	1,472
Sewall	99	983	Valley City	22	1,220
Sheldon	35	1,080	Valley Junction	36	1,403
Sheyenne	37	1,480	Verona	36	1,387
Sidney	22	954	Voss	34	842
Silver Leaf	89	1,405	Wahpeton	33, 83, 90, 99	965
Sims	23	1,962	Walcott	90	960
Sonora	87	988	Wallace	74	2,182
South Heart	24	2,482	Warren	35	926
Spiritwood	22	1,479	Wheatland	22	993
Sprague Lake	88	1,219	Wheelock	74	2,374
Spring Brook	74	2,113	White Earth	74	2,087
Stanley	74	2,252	Wild Rice	99	911
Steele	22	1,859	Williston	75	1,854
Sterling	23	1,867	Willow City	81	1,471
Stiles (M. & P.)	68	1,131	Windsor	22	1,840
Stiles (St. P., M. & M.)	87	1,139	Woodhull	99	952
Straubville	88	1,314	Woods	35	952
Sully Springs	24	2,575	Wyndmere	33	1,002
Sunnyside	23	1,658	York	73	1,612
Sweet Brier	23	1,806	Ypsilanti	36	1,381
Sykeston	37	1,628			

SOUTH DAKOTA.

Aberdeen	88, 99, 115, 120	1,300	Bath	99	1,301
			Beresford	121	1,505
Albee	86	1,184	Big Stone City	98	979
Alcester	121	1,346	Blunt	120	1,621
Alexandria	110	1,352	Bonilla	115	1,338
Alpena	115	1,319	Bowdle	99	1,995
Altamont	117	1,334	Bradley	114	1,706
Amherst	88	1,312	Bramhall	119	1,819
Andover	98, 114	1,476	Brandon	128	1,319
Appleby	120	1,711	Bridgewater	110	1,43.
Arlington	119	1,346	Bristol	98, 114	1,775
Armour	114	1,521	Britton	114	1,354
Artesian	108	1,313	Broadland	120	1,308
Ashton	115	1,296	Brookings	119	1,636
Athol	120	1,296	Bruce	120	1,640
Aurora	119	1,630	Bryant	114	1,844
Bancroft	86	1,561	Buffalo Gap	146	3,253

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SOUTH DAKOTA—continued.

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Burbank	113	1,142
Burch	88	1,296
Burkmere	117	1,748
Bushnell	143	1,694
Butler	114	1,820
Canistota	121	1,455
Canning	120	1,553
Canova	121	1,527
Canton	110	1,248
Canton Junction	110, 113	1,263
Carthage	121	1,438
Castlewood	120	1,685
Caveur	119	1,311
Centerville	121	1,229
Chamberlain	111	1,363
Claremont	88	1,302
Clark Center	117	1,789
Clear Lake	143	1,800
Columbia	121	1,304
Conde	119	1,313
Corona	100	1,173
Carson	95	1,362
Crandon	120	1,305
Deadwood	146	4,545
Dell Rapids	113	1,485
Delmont	114	1,488
Dempster	120	1,666
De Smet	119	1,726
Doland	117, 119	1,355
Durham	143	1,936
East Elrod	114	1,818
East Pierre	120	1,460
Eden	112	1,222
Egan	107, 113	1,525
Elk Point	112, 113	1,131
Elkton (B., C. R. & N.)	143	1,742
Elkton (C. & N. W.)	119	1,751
Elrod	117	1,807
Erwin	114	1,860
Esmond	121	1,433
Estelline	120	1,659
Ethan	114	1,345
Eureka	116	1,884
Fairview, Kingsbury Co.	119	1,542
Fairview, Lincoln Co	112	1,214
Faulkton (C., M. & St. P.)	116	1,573
Faulkton (C. & N. W.)	117	1,595
Forney	119	1,300
Flandreau	107	1,565
Forestburg	108	1,231
Forrestville	86	1,868
Frankfort	117	1,296
Frederick	115	1,371
Freeman	112	1,511
Fulton	125	1,332
Garden City	114	1,853
Gary	117	1,484
Gayville	113	1,167
Gettysburg	117	2,082
Goodwin	117	1,996
Groton (C., M. & St. P.)	98	1,304
Groton (C. & N. W.)	119	1,301
Grover	86	1,742
Harold	120	1,801
Harrisburg	113	1,449
Hartford	128	1,564
Hazel	86	1,765
Hecla	121	1,301
Henry	117	1,812
Hermosa	146	3,295
Highmore	119	1,800
Hillsview	116	1,849
Hitchcock	120	1,339
Holabird	119	1,795
Hosmer	116	1,901
Houghton	121	1,302
Howard	108	1,564
Huffton	88	1,307
Hurley	121	1,268
Huron (C. & N. W.)	119	1,285
Huron (St. P., M. & M.)	86	1,287
Ipswich	99	1,530
Iroquois	119, 121	1,401
James River	112	1,193
James Valley Junction	119, 120	1,312
Jefferson	112	1,118
Kampeska	117	1,766
Kent	114	1,829
Kidder	88	1,295
Kimball	111	1,788
Kransburg	117	1,982
La Bolt	86	1,362
Lake Preston	114	1,722
Langford	114	1,372
Lebanon	117	1,956
Lennox	110	1,354
Lesterville	114	1,385
Letcher	115	1,300
Loyalton	116	1,685
McCook	112	1,112
Madison	108, 114	1,669
Manchester	119	1,542
Mansfield	120	1,300
Marion Junction	110, 112	1,441

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Meckling	113	1,156
Mellette	115	1,300
Menno	112	1,324
Milbank	98, 100	1,148
Millard	116	1,640
Miller	119	1,587
Mina	99	1,432
Miranda	117	1,447
Mitchell (C., M. & St.P.)	111, 114, 115, 128	1,301
Mitchell (C., St. P., M. & O.)	128	1,312
Montrose	128	1,474
Mount Vernon	111	1,413
Naples	114	1,791
Newark	114	1,308
Nordland	119	1,846
Northville	120	1,299
Oldham	114	1,721
Ordway	120	1,306
Orient	116	1,599
Osceola	86	1,453
Palisades	95	1,457
Parker(C., M. & St. P.)	110	1,348
Parker (C. & N. W.)	121	1,340
Parkston	114	1,400
Pennington	146	4,972
Pierpont	114	1,512
Pierre	120	1,440
Plana	88	1,302
Plankinton	111	1,528
Preston	119	1,696
Puckwana	111	1,546
Putney	88	1,306
Ramona	114	1,301
Rapid City	146	3,192
Rauville	86	1,757
Raymond	117	1,458
Redfield (C., M. & St. P.)	115	1,295
Redfield (C. & N. W.)	117, 120	1,300
Ree Heights	119	1,731
Revillo	140	1,208
Rockham	117	1,394
Roscoe	99, 116	1,826
Rousseau	120	1,427
Rudolph	120	1,301
Running Water	112	1,220
St. Lawrence	119	1,580
Salem (C. & N. W.)	121	1,517
Salem (C., St. P., M. & O.)	128	1,520
Scotland	112, 114	1,347
Seneca	117	1,911
Sheffield	86	1,300
Sherman	95	1,496
Sioux Falls (B., C. R. & N.)	113, 144	1,400
Sioux Falls (C., M. and St. P.)	113	1,393
Sioux Falls (C., St. P., M. & O. and Ill. Cent.)	113, 128	1,397
Sioux Falls (St. P., M. & M.)	95	1,420
Sioux Falls, zero of city levels	113	1,307
Sioux Falls Junction	107, 113	1,514
Spain	114	1,327
Spencer	128	1,387
Springdale	144	1,400
Springfield	112	1,234
Sturgis	146	3,467
Summit	98	2,000
Toronto	143	1,994
Tripp	114	1,563
Troy	140	1,885
Tulare	115	1,317
Turton	119	1,323
Tyndall	112	1,418
Utica	113	1,387
Valley Springs	128	1,395
Verdon	119	1,304
Vermilion	113	1,150
Vienna	86	1,837
Vilas	121	1,480
Virgil	115	1,341
Volga	119	1,636
Volin	121	1,181
Wakonda	121	1,396
Walrath	86	1,184
Warner	115	1,301
Watertown (C. & N. W.)	117, 120	1,733
Watertown (M. & St. L. and B., C. R. & N.)	140, 143	1,734
Watertown (St. P., M. & M.)	86	1,726
Watertown Junction	119, 120	1,604
Waubay	98	1,813
Waverly	140	1,992
Webster	98	1,842
Wessington	119	1,419
Westport	115	1,333
White	143	1,778
White Lake	111	1,646
White Rock	99	973
Whitewood	146	3,640

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SOUTH DAKOTA—continued.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Willow Lakes	86	1,786	Worthing	110	1,364
Wilmot	100	1,196	Yale	86	1,340
Wilson	140	1,366	Yankton (C., M. & St. P.)	113	1,196
Wolsey (C., M. & St. P.)	115	1,353	Yankton (C. & N. W.)	121	1,206
Wolsey (C. & N. W.)	119	1,348	Zell	117	1,365
Woonsocket	108, 115	1,308			

MONTANA.

Ainslie	24	2,274	Clermont	25	2,950
Allard	24	2,246	Clough Junction	25, 39	4,315
Arlee	26	3,059	Coal Spur	25	4,737
Ashfield	76	2,205	Corbin	38	4,752
Assiniboine	76	2,576	Corvallis	39	3,474
Avon	25	4,677	Cruse	39	4,585
Bearmouth	25	3,789	Culbertson	75	1,918
Beaver Hill	24	2,757	Custer	24	2,727
Beaverton	75	2,168	Dailey's	38	4,915
Bedford	25	3,884	De Smet	26	3,215
Belgrade	25	4,437	Dixon	24	2,322
Belknap	26	2,405	Dodson	76	2,279
Benton	76	2,350	Drummond	25, 39	3,945
Big Horn	24	2,690	Dry Fork	76	2,984
Big Sandy	76	2,690	Duncan	26	2,499
Big Timber	25	4,072	Eddy	26	2,415
Billings	25	3,117	Elliston	25	5,038
Birdseye	25	4,210	Elton	25	4,282
Blair	75	1,920	Emigrant	38	4,862
Blatchford	24	2,247	Eureka	76	2,301
Bonita	26	3,566	Evaro	26	3,948
Bonner	26	3,297	Exeter	76	2,254
Boulder City	38	4,920	Fallon	24	2,208
Bowdoin	76	2,209	Flint	39	4,834
Box Elder	76	2,669	Florence	39	3,249
Bozeman	25	4,754	Flowerree	77	3,203
Brisbin	38	4,682	Forsythe	24	2,514
Brockton	75	1,945	Fort Belknap	76	2,401
Bull Mountain	24	2,812	Fort Keogh	24	2,367
Butler	25	4,727	Gallatin	25	4,032
Butte City	25	5,703	Garrison	25	4,317
Cairo	76	2,837	Glasgow	75	2,087
Calais	75	1,934	Glendive	24	2,069
Calvin	38	5,556	Gold Bar	38	4,490
Carlan	25	3,684	Gold Creek	25	4,255
Cataract	38	5,274	Gordon	25	4,907
Chelsea	75	1,980	Great Falls	77	3,312
Chicory	38	4,847	Greycliff	25	3,847
Chinook	76	2,401	Hamilton	25	4,242
Cinnabar	38	5,172	Harlem	76	2,350
Clancy	38	4,317	Hathaway	24	2,428
Clasoil	25	4,125	Havre	76	2,452

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MONTANA—continued.

	Page.	Feet above the sea.		Page.	Feet above the sea.
Helena	25, 38	3,932	Perma	26	2,495
Heron	26	2,261	Phillipsburg	39	5,167
Hinsdale	75	2,162	Placer	25	4,292
Hodges	24	2,508	Pompey's Pillar	24	2,871
Hodgson	38	4,858	Poplar	75	1,955
Horse Plains	26	2,463	Portage	77	3,413
Horton	24	2,395	Prickly Pear Junction	25, 38	3,889
Howard	24	2,561	Rapids	25	3,517
Huntley	25	3,014	Ravalli	26	2,692
Jefferson	38	4,537	Red Mountain Junction	25, 38	3,909
Jefferson Junction	38	4,515	Reedpoint	25	3,687
Jocko	26	2,509	Rimini	38	5,183
Johnstown	77	3,311	Riverside	24	2,779
Kessler's	38	3,930	Rosebud	24	2,462
Kilva	75	1,955	Saco	76	2,175
Kintyre	75	2,082	Sanders	24	2,595
Lanark	75	1,976	Savoy	76	2,324
Laredo	76	2,627	Sidney	77	3,098
Laurel	25	3,255	Sphinx	38	5,072
Lenox	75	2,072	Springdale	25	4,190
Livingston	25, 38	4,487	Stevensville	39	3,299
Lloyd	25	4,297	Stillwater	25	3,572
Lou Lou	39	3,175	Stockholm	75	2,093
McClellan	24	2,687	Stone	39	4,539
Macon	75	1,976	Tampico	75	2,105
Magpie	25	3,981	Terry	24	2,242
Malta	76	2,242	Teton	76	2,626
Marias	76	2,561	Thermal Springs	38	4,027
Marysville	39	5,376	Toledo	76	2,455
Merrill	25	3,657	Toston	25	3,915
Miles City	24	2,355	Townsend	25	3,811
Milk River	75	2,048	Trail Creek	38	4,822
Milton	24	2,116	Trout Creek	26	2,375
Mingusville	24	2,652	Tunis	77	2,957
Mission	25	4,345	Vandalia	75	2,120
Missoula	26, 39	3,197	Verona	76	2,708
Moose Creek	38	4,831	Victor	39	3,391
Moreland	25	4,229	Wagner	76	2,258
Muir	25	5,502	Wallace	26	3,450
Mullan	25	5,532	Watson	77	3,470
Myers	24	2,659	Wayne	76	2,332
Nashua	75	2,060	Whately	75	2,086
New Chicago	39	4,037	Wickes	38	5,152
North Fork	76	2,381	Willows	75	1,889
Noxon	26	2,186	Wolf Point	75	1,995
Oswego	75	2,018	Yantic	76	2,431
Painted Rock	25	3,955	Zurich	76	2,368
Park City	25	3,387			

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NEBRASKA.

(Fremont, Elkhorn and Missouri Valley Railroad.)

	Page.	Feet above the sea.		Page.	Feet above the sea.
Chadron	145	3,360	Long Pine	145	2,396
Crookston	145	2,670	Norfolk Junction	145	1,516
Fort Robinson	145	3,775	Stuart	145	2,151
Fremont	145	1,193	Thacher	145	2,649
Gordon	145	3,547	Valentine	145	2,579

WYOMING.

(Fremont, Elkhorn and Missouri Valley Railroad.)

Casper	145	5,118	Lusk	145	5,007
Douglas	145	4,810	Van Tassell	145	4,727
Fisher	145	4,752			

IDAHO.

(Northern Pacific Railroad.)

Algoma	26	2,214	Clark's Fork	26	2,086
Athol	26	2,210	Granite	26	2,290
Cabinet	26	2,187	Hope	26	2,108
Chilco	26	2,450	Sand Point	26	2,100

WASHINGTON.

(Northern Pacific Railroad.)

Ainsworth	26	351	Kalama	27	33
Alderton	29	65	Kennewick	27	350
Badger	27	687	Kiona	27	499
Bender	27	639	Lakeview	27	324
Boisé Creek	28	685	Lind	26	1,363
Buckley	29	716	Mabton	27	722
Cañon	28	1,790	Marshall Junction	26	2,134
Cascade	29	473	Martin	28	2,777
Castle Rock	27	83	Maywood	25	1,345
Centralia	27	207	Meeker	29	62
Chehalis	27	204	Nelson's	28	2,032
Clealum	28	1,912	Palmer	28	874
Cole	28	2,164	Palouse Junction	26	858
Eagle Gorge	28	1,088	Pasco Junction	26, 27	385
Easton	28	2,171	Prosser	27	668
Ellensburg	28	1,513	Puyallup	29	45
Eltopia	26	600	Relief	27	565
Ramsdaw	28	734	Reservation	29	12
Harriston	26	1,950	Ritzville	26	1,825
Hot Springs	28	1,544	Roza	28	1,251
Idaho Line	26	2,128	Satus	28	680

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WASHINGTON—continued.

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Selah	28	1,151	Thorp	28	1,664
Simcoe	28	863	Thrall	28	1,437
South Prairie	29	423	Toppenish	28	763
Spokane Falls	26	1,910	Trent	26	1,969
Sprague	26	1,908	Umtanum	28	1,351
Stampede	28	2,746	Walla Walla	26	925
Stevens	26	2,282	Wallula Junction	26	326
Stuck Junction	29	100	Weston	28	1,854
Tacoma	27, 29	31	Winlock	27	328
Teanawray	28	1,839	Yakima	28	1,069
Tenino	27	315	Yelm Prairie	27	387

OREGON.

(Northern Pacific Railroad.)

Alkali	27	232	Juniper	26	318
Bonneville	27	60	Mosier	27	100
Bridal Veil	27	46	Portland	27	30
Celilo	27	160	Quinn's	27	236
Clarnie	27	214	Troutdale	27	60
Columbia City	27	90	Umatilla Junction	26	302
Coyote	27	257	Viento	27	104
Dalles	27	106	Willows	27	234
Grant's	27	180			

ONTARIO.

Barclay	41	1,251	Hawk Lake	42	1,289
Beaver	42	1,186	Linkooping	40	1,534
Bonheur	41	1,530	Lofoden	40	1,078
Bridge River	41	1,543	Martin	41	1,557
Brulé	41	1,355	Murillo	40	947
Buda	40	1,473	Nordland	40	1,543
Butler	41	1,423	Ostersund	42	1,105
Carlstad	41	1,515	Oxdrift	41	1,162
Deception	42	1,136	Parrywood	41	1,252
Eagle River	41	1,186	Port Arthur	40	628
English River	41	1,517	Raleigh	41	1,440
Falcon	41	1,509	Rat Portage	42	1,087
Finmark	40	1,180	Rossland	42	1,128
Fort William	40	615	Savanne	41	1,506
Gilbert	41	1,217	Summit	42	1,385
Ignace	41	1,487	Taché	41	1,366
Ingolf	42	1,184	Upsala	41	1,579
Kalmar	42	1,217	Vermilion Bay	41	1,221
Kaministiquia	40	1,013	Wabigoon	41	1,211
Keewatin	42	1,075			

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Alexander	44	1,406	McGregor	44	961
Arden	53	1,086	Macdonald	53	837
Arnaud	49	794	Manitou	50	1,586
Austin	44	1,005	Marquette	43	807
Bagot	44	935	Maryland	51	844
Barnsley	51	854	Meadows	43	793
Basswood	54	1,949	Melbourne	44	1,248
Beausejour	43	814	Midway	53	975
Bergen	43	784	Minnedosa	54, 55	1,670
Binscarth	55	1,713	Monmouth	43	879
Bird's Hill	43	759	Morden	50	978
Birtle	55	1,703	Morris	49	772
Boissevain	50	1,683	Neepawa	54	1,206
Brandon	44	1,194	Newdale	54	1,975
Bridge Creek	54	1,600	Niverville	49	774
Burnside	44	872	Oak Lake	44	1,415
Carberry	44	1,258	Otterburne	49	779
Cartwright	50	1,533	Pilot Mound	50	1,549
Chater	44	1,213	Poplar Point	43	815
Clearwater	50	1,498	Portage la Prairie	43, 52	854
Cross Lake	42	1,092	Rapid City	55	1,579
Crystal City	50	1,513	Reaburn	43	806
Cypress River	51	1,232	Rennie	42	1,053
Darlingford	50	1,560	Riverdale	55	1,636
Darwin	42	971	Rosenfeld	49	796
Deloraine	50	1,644	Rosser	43	796
Dominion City	49	785	Russell	55	1,830
Douglas	44	1,222	St. Boniface	49	751
Dufrost	49	791	St. James	49	764
East Selkirk	43	743	St. Norbert	49	767
Elkhorn	44	1,630	Sewell	44	1,255
Elm Creek	51	819	Shelly	43	929
Emerson	49, 50, 81, 169	790	Shoal Lake	54	1,812
Foxwarren	55	1,742	Solsgirth	55	1,789
Gladstone	53	883	Starbuck	51	781
Glenboro	51	1,231	Stonewall	52	810
Gonor	43	757	Stony Mountain	52	773
Gretna	49, 84, 189	829	Strathclair	54	1,901
Griswold	44	1,417	Sydney	44	1,232
Hargrave	44	1,579	Telford	42	1,059
Harrowby	55	1,593	Thornhill	50	1,814
Headingly	51	776	Treherne	51	1,212
High Bluff	43	829	Tyndall	43	796
Holland	51	1,237	Virden	44	1,444
Holmfield	50	1,551	West Lynne	50	790
Kelloe	55	1,814	West Selkirk	52	736
Kemnay	44	1,364	Westbourne	53	831
Killarney	50	1,625	Whitemouth	43	907
La Rivière	50	1,904	Winnipeg	43, 49, 51, 52	757
La Salle	49	770	Winnipeg Junction	43, 49	752
Little Pembina	50	1,649	Woodside	53	858
Lower Fort Garry	52	754			

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WASHINGTON, D. C., *July*, 1891.

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1891

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J. W. POWELL, DIRECTOR

THE

VISCOSITY OF SOLIDS

BY

CARL BARUS.

WASHINGTON
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1891

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PREFACE.

This bulletin is a second contribution to the general investigation of the physical contents of rocks, the experiments concerning which follow a general plan devised by Mr. Clarence King.

Questions bearing directly on the viscosity of rock masses make up so large a part of Mr. King's geological observations, that the duty of inquiring into the physics of this enormously complicated subject devolved seriously upon me. Above all things some form of reliable working hypothesis was to be discovered; and this is what the present bulletin endeavors to accomplish. I believe the physical hypothesis has been found and that the data afford substantial corroboration of Maxwell's theory of the viscosity of solids.

The method by which I attempt to arrive at the result in question consists in investigating the details of viscous behavior of steel. Steel has a phenomenal quality, in that it can be made to pass continuously from an extreme of brittle hardness almost to soft plasticity. Hence its value in serving as a test of any theory.

Curiously enough, viscous deformation (Nachwirkung) is strikingly pronounced at the hard and brittle end of the scale, whereas soft steel is relatively rigid. These facts are established in Chapter I, of which they form the larger part. To interpret the striking results of Chapter I it is necessary to consider them from a more general point of view. Consequently Chapter II investigates them further with regard to their general truth under variable conditions of temperature and of stress. But the full interpretation is not attempted until Chapter III, where, together with other relevant matter, they are shown to bear directly on the fundamental hypotheses of Maxwell's theory of the viscosity of solids.

Chapter IV applies a magnetic method to the study of the behavior of a strained atomic configuration, and is thus an important deduction from Chapter III.

Chapter V finally exhibits the solidity of the three states of aggregation. The results show an astounding range of variation, inasmuch as viscosity on passing from extreme fluid to extreme solid changes from at most 10^{-5}, to at least 10^{20}.

By selecting steel as the chief source of evidence I gain a second important advantage. *The researches* of Dr. Strouhal and myself have

thrown new light on a number of the physical qualities of steel, some of which are closely allied to the subject in hand. Thus there exists a reciprocal relation between the earlier bulletins of the Geological Survey, No. 14, No. 27 (pp. 30–60), No. 35, and No. 42 (pp. 98–131), and the present bulletin, by which clearness of conception regarding the physics of the iron-carburets is promoted.

The notation has been made uniform throughout the work, and the data reduced to the same standard. This occasioned much extra labor, since it involved a new computation of the chief results of Chapters II and III. However, seeing that the unity of the book could be much enhanced thereby, the time was not grudgingly spent.

Meantime the researches on solid viscosity have been considerably extended. I have now nearly ready for the press a sequel[1] to this volume, in which the *molecular* changes which promote viscous motion are specially discussed. The results enable me to submit a general theory of solid molecular structure, and they therefore fitly make up a second part of the continued series of researches of which this bulletin constitutes the first part.

I may add in concluding, that the researches on steel were begun by Dr. Strouhal and myself and continued to such a stage of progress as made it advisable for us to publish subsequent investigations together. But the serious delays incident to epistolary communication at best, and the great distance between us (Prague–Washington), has dictated, very much to our regret, a dissolution of literary partnership. The science of to-day is more and more exactingly a science of specialized responsibilities, and the connection between a statement and its author can not be too direct or too obvious.

CARL BARUS.

LABORATORY U. S. GEOLOGICAL SURVEY,
Washington, D. C., March 15, 1890.

[1] Cf. Annual Report of the Director for the fiscal year 1888–'89.

THE VISCOSITY OF SOLIDS.

By Carl Barus.

CHAPTER I.

By Carl Barus and Vincent Strouhal.

THE VISCOSITY OF STEEL AND ITS RELATIONS TO TEMPER.

INTRODUCTION.

1. In Bulletin No. 42, U. S. Geol. Survey, p. 131, we expressed the belief that the qualities of retaining magnetism exhibited by steel would probably stand in relation to the viscous properties of the metal. In the present chapter we make a first search for such a relation. The work is restricted to torsional viscosity because it usually exists in larger amount, and is much more accurately measurable than any of the other manifestations of viscosity. Possibly it may be brought more rationally into comparison with magnetic phenomena. We therefore develop partially (i. e. so far as is necessary for our especial purposes) a very sensitive differential method for the study of torsional viscosity.[1] Having applied it to steel, we compare the results obtained with the known behavior of permanent linear magnets, tempered under like conditions. During the course of the experiments we incidentally come upon certain ulterior results (viscosity of iron, glass).

In our magnetic comparisons we have endeavored to avoid prematurity. Many inferences of the original draught have been cropped. We do not wish to ignore the magnetic effect of the chemical changes of steel. We have merely endeavored to *circumscribe* the magnetic effect of carburation, by exploring the magnetic importance of certain mechanical properties of steel. To do this we have studied, abstractly as it were, the occurence of permanent magnetism in a medium of continuously varying viscosity, without insisting on an inherent relation between retentiveness and viscosity.

[1] Independently of ourselves, as we subsequently found, a similar méthod was used by Boltzmann and by O. E. Meyer (Pogg. Ann., vol. 154, 1875, p. 357).

LITERARY NOTES.

2. The necessary existence of viscosity in solids was pointed out, discovered, and its nature described by Weber;[1] but it is to Kohlrausch's[2] extensive researches that we owe the bulk of our present knowledge. A new method of research was indicated by Sir William Thomson,[3] which method was developed, independent of Thomson we believe, by Streintz[4] and by Schmidt.[5] Thomson[6] concisely defined the terms now in English use and followed by Maxwell (Heat, Chapter II).

PLAN OF RESEARCH.

3. We proposed at first to study the viscosity of steel from two distinct standpoints: one part of our work was to consider viscosity in its relations to temperature; the other part, viscosity in its relations to hardness. Indeed, we have as yet no data at all of this kind for steel. For other substances Kohlrausch[7] and after him Streintz[8] and Pisati[9] had already studied viscosity and temperature with some detail though in a direction differing somewhat from our own. Very recently, however, Schroeder[10] has experimented in a line of research quite identical with the one upon which we had determined; and though his data do not include steel, the results obtained for other metals are sufficiently pronounced to make a special investigation of steel appear superfluous, at least so far as regards its present bearing on our work. Schroeder[11] finds "Der bei 100° begonnene Verlauf der Nachwirkung wird durch Abkühlung des Drahtes auf Zimmertemperatur unterbrochen; nach

[1] Weber: Götting. Gelehrt. Anz., St. 8, 1835; Pogg. Ann., vol. 24, 1835, p. 247; ibid., vol. 54, 1841, p. 1; Comm. Soc. Götting., vol. 3, 1841, p. 45. Weber's researches express the amount of viscous deformation in terms of time by a hyperbolic formula with three constants.

[2] Kohlrausch: Pogg. Ann., vol. 119, 1863, p. 337; ibid., vol. 128, 1866, pp. 207, 399; ibid., vol. 155, 1875, p. 579; ibid., vol. 158, 1876, p. 337. The author subjected fibers of a great number of substances to torsional, tensile and flexural stress, and he discusses the amount of deformation in each case in its dependence on time and on temperature. The results are too elaborate to be excerpted here. The author finds it necessary to use exponential relations with three and even four constants to describe the results completely. In this place we advert, moreover, to the papers of Neesen (Pogg. Ann., vol. 153, 1874, p. 498; ibid., vol. 157, 1876, p. 579; Wied. Ann., vol. 7, 1879, p. 460), of Braun (Pogg. Ann., vol. 119, 1876, p. 337), of Wiedemann (Wied. Ann., vol. 6, 1879, p. 496) which supply details of critical discussion. Perhaps we may even add Pernet's well known thermometric researches (Carl's Repertorium, vol. 11, 1875, p. 257, and elsewhere).

[3] Sir William Thomson: Phil. Mag. (IV), vol. 30, 1865, p. 63. Thomson refers the loss of energy of of vibration to the existence of molecular friction.

[4] Streintz: Pogg. Ann., vol. 153, 1874, p. 387; Wien. Ber., vol. 69, part 2d, 1874, p. 355. Using a vibration method the author discusses elaborately the effect of viscosity on the logarithmic decrement.

[5] Schmidt: Wied. Ann., vol. 2, 1877, pp. 48, 241, supplements Thomson's and Streintz's results, and is able to express logarithmic decrement in terms of time by Weber's formula of three constants. We may add Cohn (Wied. Ann., vol. 6, 1879, p. 403), Hopkinson (Phil. Trans., 1877), Warburg (Wied. Ann., vol. 13, 1881, p. 141), Auerbach (Wied. Ann., vol. 14, 1881, p. 308), Kohlrausch (Pogg. Ann., vol. 128, 1886), Ewing (Phil. Trans., 1885, p. 545) and others who discuss viscosity as manifesting itself in phenomena of conductivity (Cohn), residual static charge (Hopkinson, Kohlrausch), magnetism (Auerbach, Warburg, Ewing and others).

[6] Thomson: loc. cit.

[7] Kohlrausch: Pogg. Ann., vol. 128, 1866, p. 216; ibid., vol. 158, 1876, p. 371.

[8] Streintz: Wien. Ber., vol. 69, 1874, p. 337; also Schmidt, loc. cit.

[9] Pisati: Wien. Ber., vol. 80, 1879, p. 427. Also Gaz. Chim. Ital., 1876, 1877.

[10] Schroeder: Wied. Ann., vol. 28, 1876, p. 369.

[11] *Schroeder: Ibid., p. 388.*

erneuter Erwärmung auf 100° wird die vorher unterbrochene Drehung fortgesetzt." We pointed out[1] that in case of drawn metals, of quenched glass (Rupert's drops) and we inferred also in case of tempered steel, energy has been stored up in virtue of the rigidity of the material; and that on exposure to temperature (annealing), the available excess of stress is made to produce the observed viscous deformation precisely in the way in which Schroeder has found it for applied torsional stress. Nevertheless, the behavior of steel, when considered in all its details, is much more complicated and is, indeed, quite unique, as will be indicated in the course of this chapter.

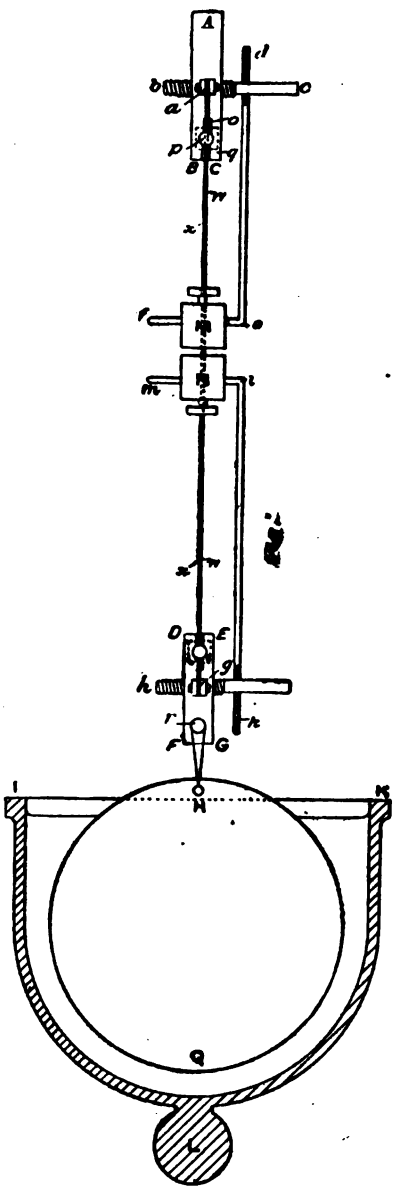

FIG. 1.—Bifilar apparatus for torsional viscosity; scale ¼.

METHOD OF EXPERIMENT.

APPARATUS.

For the reasons given the scope of this chapter has been limited to a study of the viscosity of steel, in its relations to temper. We endeavor therefore to determine the difference of viscosity which corresponds to a given known difference of hardness. The following differential method of measurement, the principle of which can be made clear in a few words, naturally suggests itself:

Bifilar apparatus.—Given a pair of steel wires, one of which is always glass-hard, the other of known temper; let them be made the threads of a *bifilar suspension* provided with suitable means for the measurement of the angular motion of the line defined by the lower double point of attachment, relative to the upper line of attachment; finally let a twist of $+T$ be imparted to one steel wire, a twist of $-T$ to the other. If now the system be left to itself, and if the two wires be equally viscous the

[1] Bull. U. S. Geol. Survey, *No. 14, 1885, p. 196*; Am. Jour. Sci. (III), vol. 31, 1886, p. 452.

bifilar system cæteris paribus will remain at rest. If on the other hand the viscosities be unequal, the lower free part of the bifilar will move around the vertical let fall from the upper part. The sign of this angular motion will be that of the twist of the wire of greater viscosity; its amount cæteris paribus directly dependent on the difference of viscosity of the pair of wires under experiment. One of the forms of apparatus actually used is given in the annexed diagrams, Figs. 1 to 3, the former on a scale of $\frac{1}{4}$. The couple of steel wires *awwg* and *axxg* to be tested, are fastened above to a massive piece of brass *ABC* and below to a similar piece *DEGF*. *ABC* is fixed firmly to the wall at some distance from it, and all incidental motion or displacement is registered by the mirror *M*, adjustable at pleasure by aid of the screw-arms *fed* and *bc*. *DEGF* is free to move under the influence of the bifilar couples and motion is similarly registered by the mirror *N* adjustable at pleasure by aid of the screw arms *mlk* and *h*. To keep the line of symmetry of the piece *DEGF* vertical, to deaden incidental vibrations, and to give general stability to the whole bifilar adjustment, we suspended a heavy lead disk *HQ* (5 lbs.) from the screw *r*. *HQ* is partially immersed in water contained in a glass bell-jar *ILK* also (adjustably) attached to the wall.

The steel wires are inserted and then fastened in the apparatus as follows: To keep the two steel wires (about 33^{cm} long) under a permanent strain of torsion, each is softened about 2^{cm} from the ends inward. The soft parts are then bent into a hook-like loop just large enough to slide over the screws of the little brass bolts *a* and *g*. Having fastened the lower ends by the bolt *g*, the upper ends are each twisted 180° against each other and then also fastened by the bolt *a*.

The ends of this twisted system are now to be secured to the blocks of brass *ABC* and *DEGF*. One method of fastening is given ($\frac{1}{2}$ actual size) in Fig. 2, the parts of which are lettered similarly to Fig. 1. The two wires, *w* and *x*, are pressed firmly against a little rectangular piece of steel *o*, by aid of the bolt *pp'* and the nut *qq'*. The bolt is provided with a square hole near its head, through which *o* and the steel wires may easily be passed. A little pin prevents *o* from rotating around the axis of the screw, thus diminishing liability to breakage. In the apparatus figured it is necessary to slide the bolts *pp'* over the wires *w*, *x*, before the torsion is applied by fastening *a*.

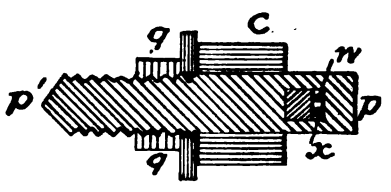

FIG. 2.—Device for suspension; scale, $\frac{1}{2}$.

In Fig. 3 the same apparatus is given in side elevation (sectional), and as the same lettering is here used as in Figs. 1, 2, this diagram is at once intelligible. It indicates in a clearer way the method of insert-

ing and fastening the twisted systems wx, wx, with reference to which wires the experiments are made.

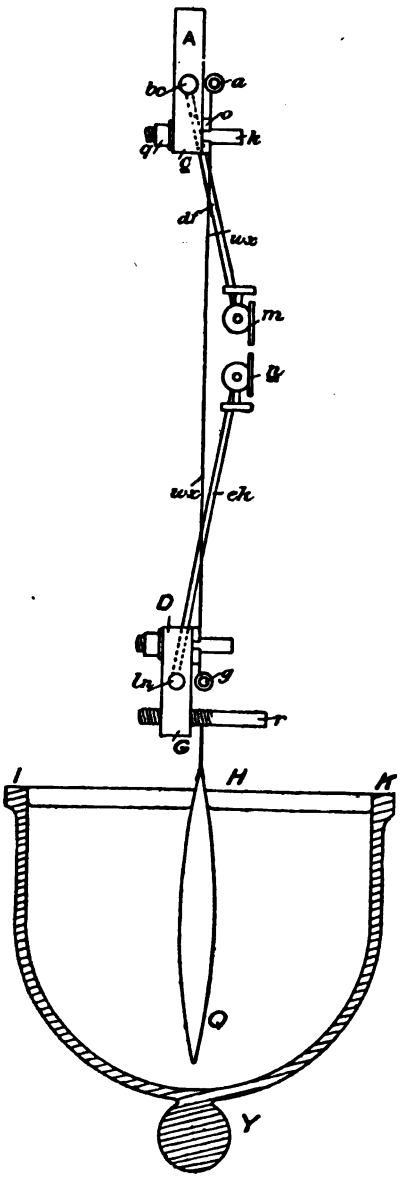

FIG. 3.—Side elevation of the apparatus shown in Fig. 1.

In a more convenient form of apparatus, perhaps, we replace the brass blocks ABC and $DEGF$ by little hand vises, the axle of the lower one of which has been perforated and fitted with a screw subserving the purposes of r in the figure. By aid of a disc of lead vertical symmetry of the whole apparatus is here also maintained.

The advantage of this form of apparatus, apart from our own special purposes, is that with a single adjustment, the viscous movement can be traced with extreme accuracy for an indefinite length of time. There is no doubt that in some of the cases examined such motion will demonstrably exist even for a year after the torsion has been imparted. Kohlrausch's method is an absolute method; but his wire must be twisted and untwisted once for each observation. The method of logarithmic decrement is difficult of interpretation, and is really a complex method and limited to short intervals of time.

In experimenting with glass it was necessary to modify the apparatus so that twists less than $T=180^{\circ}$ could be applied. This is easily done by perforating the screw of the upper bolt and passing the glass fiber through the hole. Torsion in any amount may then be applied to the projecting fiber.

5. *Tubular apparatus.*—Our second (tubular) apparatus combines with the advantages of the one just sketched, the ulterior desideratum of enabling the observer to follow the viscous detorsion immediately after applying stress; and therefore also the advantage of exhibiting the

effect of positive torsion immediately succeeding negative torsion and vice versa; or of studying the effect produced by an indefinite number of alternations of the sign of the twist. In the second form of apparatus the wire is introduced into a narrow tube just large enough to surround it. The tube is fixed above and fastened to the wire below. Twist is imparted to the wire and through it to the tube. The observations, in other respects, are conducted as above.

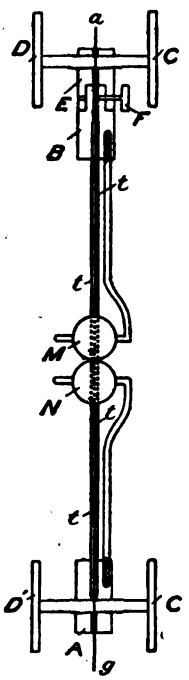

FIG. 4.—Sectional elevation of the tubular apparatus.

Figure 4 is a sectional elevation of the tubular apparatus. Here E is a massive cylinder of brass, in the lower socket of which the reduced end of the cylinder B fits snugly, so as to be free to rotate around the vertical, unless fastened by the steel pin F. E and B are axially perforated, and B carries the tube $tttt$, which in its turn carries the lower massive cylinder of brass A. The steel wire to be tested, ag, is inserted through the perforations in E, B, A, and securely fastened against rotation by the lateral screws CD and $C'D'$. N is the movable mirror, adjustably fastened to the lower bob A; M is the fixed mirror (fiducial mark) adjustably fastened to B.

The cylinder B is stationary, being secured by a clamp not shown in the figure. Twist is imparted to the system of tube $tttt$ and wire ag, by withdrawing the pin F, rotating E, and then again inserting the pin.

6. *Unifilar apparatus.*—A third form of apparatus in which the wires are countertwisted unifilarly is described in Chapter II.

METHOD OF OBSERVING.

7. In both forms of apparatus, angles are registered by Gauss' method of telescope[1] and scale. We secure extreme accuracy by using two mirrors, one of which (stationary) furnishes a reliable fiducial mark for the other (movable). These mirrors are easily so adjusted that their respective scale-images appear *simultaneously* in the field of the telescope, one above the other and intersected by the same cross-hair. Indeed, it would not be difficult so to arrange this device that the stationary image could be used as a vernier on the moving image.

METHOD OF TEMPERING.

8. *Quenching.*—The wires used (Stubs's steel) were hardened galvanically as described elsewhere.[2] To Prof. H. A. Rowland, who placed his

[1] Three wood screws, the head of one of which is planed, of another hollowed out conically, make a good adjustable plane-dot-slot arrangement.

[2] Bull. U. S. Geol. Survey, No, 14. p. 29; Wied. Ann., 1880, vol. 11, p. 932. Cf. § 55.

dynamo-electric machine at our disposal for this purpose, and favored us with the benefit of his advice during almost the entire afternoon, we owe our cordial thanks.

The apparatus for quenching deserves special description, being simplified in general character and made available for divers ulterior purposes. It is given perspectively in Fig. 5, slightly tilted forward to

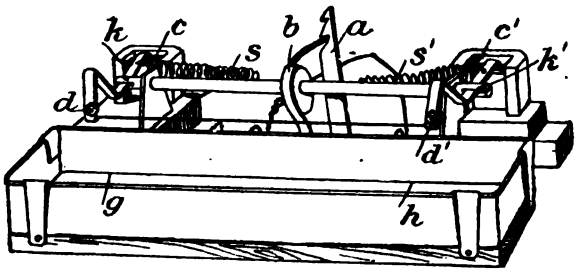

FIG. 5.—Galvanic apparatus for quenching steel.

show the parts. Here *gh* is the trough of sheet iron in which quenching is to take place. The wire *dd'*, kept slightly stretched by two horizontal beak-shaped arms *dk*, *d'k'* which are swiveled on the axle *kk'*, is suspended horizontally just above the water in *gh*. A spring at *b*, tends to snap the wire into the water, unless prevented by the notched stop *a*. *b*, therefore, tends to rotate the axle *kk'* which to secure insulation is made of hard rubber. Finally the rear ends of the said beak-shaped arms, are bent downward and amalgamated. During the suspension of the steel wire they dip into oblong adjustable troughs of mercury *c*, *c'* which communicate with a battery or dynamo. Finally, two spiral springs, *s*, *s'*, by drawing the rear ends of the arms together, (swivel at *k* and *k'*) keep the wire stretched, as has been stated, even at red heat. The level of mercury in *c* and *c'* is so adjusted that the current of the battery is broken the moment the wire touches the surface of the water.

The method of operating is easily understood. Having closed the current and heated the wire to the degree of redness desired, the pin at *a* is quickly released, which whips the wire suddenly into the water and at the same time, as already stated, automatically breaks the currents. The cold wire will be found quenched glass-hard, or indeed harder, so that specific resistance may run as high as $s=50$ microhms. As regards homogeneity, too, these wires are exceptionally excellent, as will be indicated below, twenty wires of about 150^{cm} each in length having for certain special purposes been examined per 2^{cm} of length of each.

The present apparatus offers many conveniences by which quenching is appreciably facilitated. This will be seen by comparing it with the older galvanic apparatus.[1] Alterations, moreover, are easily introduced by which quenching may be effected in water or metal of any tempera-

[1] Bull. U. S. Geol. Survey, No. 14, 1885, p. 29.

ture (simply heating the trough *gh* with burners placed underneath); and by which the rod may be quenched from any temperature of red heat corresponding to known intensity of the galvanic current which heats the wire.

9. *Annealing.*—The annealing was effected by drawing the glass-hard wires through a zone of constant temperature by clockwork.[1] Cf. § 55.

This operation is also of such importance and so difficult to accomplish in case of very long wires, that an apparatus by which it is satisfactorily done deserves description. It is given in perspective view in Fig. 6, and consists essentially of a Barus' *boiling tube T*, containing the substance boiling at the temperature at which annealing is to take place. Water 100°, aniline 185°, diphenylamine 310°, mercury 360°, sulphur 450°, are usually sufficient for annealing work. Other substances are given elsewhere.[2] These substances are easily boiled by aid of the ring burner surrounding the tube, and annealing is commenced when the thermal distribution has become stationary. The central tube of the boiling-tube *T* is prolonged downward by attaching the closed tube *t*, long enough to envelope the cold steel wire to be annealed. This wire (or wires) is suspended from a very fine copper filament, the upper end of which is fastened to the drum or disc *C* of the adjustable clock. When the clock has been set in motion the wire is slowly drawn through the zone of ebullition, by the revolving drum *C*. All parts are attached to a ring stand as shown, and easily adjustable. In the figure the wires are given at *w* prolonged, in which position they are about half way through the zone of ebullition. If *h* be the height of the zone and *R* the radius of the disc *C* revolving once per hour, then

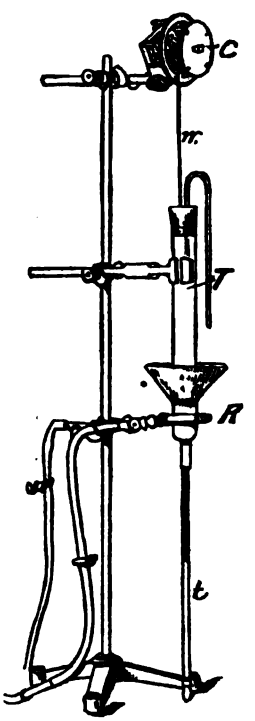

FIG. 6.—Apparatus for annealing long steel wire.

$$t=\frac{h}{2\pi R}$$

is the time of annealing in hours. Again by making $h=2\pi$, the time of exposure in hours is the reciprocal of the radius of the disc in centimeters.

This method of annealing is exceedingly convenient at high temperatures, as only a very narrow zone of constant temperature is called for. Between 500° and 1,000° such work is done by replacing the annealing tube by an annealing crucible of porcelain or fire clay of the

[1] Barus: Am. Jour. Sci. (III), 1886, vol. 32, p. 279.
[2] Barus: Bull. U. S. Geol. Survey, No. 54, 1889, p. 87.

form given in Fig. 7, the crucible being placed in a suitable Fletcher furnace, as shown in Bulletin No. 54. Cadmium, zinc bismuth, may then be used for high temperature boiling points and the rods suitably protected by atmospheres of hydrogen or carbon dioxide.

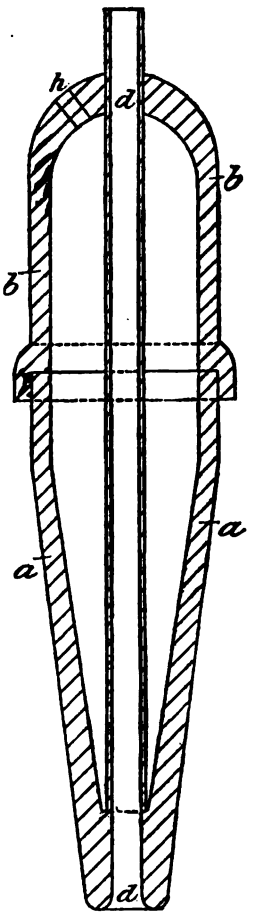

FIG. 7.—"W" crucible for annealing.

ELIMINATION OF ERRORS.

10. The steel wire to be used in these experiments are all about $0{\cdot}1^{cm}$ in thickness. Hence to determine the condition of equilibrium or motion in the torsional apparatus described, it is necessary to consider the respective moments of the bifilar couple (M_b), of the torsional couple ($M\tau$) and of the flexural couple (M_f), by which the movable end is actuated.

The moment of the bifilar couple has the well known form[1]

$$M_b=\tfrac{1}{4}\frac{\lambda\lambda'}{l}mg \sin \alpha \quad . \quad . \quad . \quad . \quad (1)$$

where λ and λ' are respectively the distance apart of the upper ends and the lower ends of the bifilar wires, l the vertical distance and α the horizontal angle between the lines λ and λ', mg the weight of the whole suspended adjustment. To mg should be added one-half the weight of the wires.

The moment of the torsion couple is $M_\tau=\tau\alpha$, where τ is the sum of the torsional coefficients of the wires. This applies because the sum of the stored torsional moments, for $\alpha=0$, is $T+(-T)=0$. We may give M_τ an experimentally convenient form by substituting for τ the approximate value derived in elastics. We obtain

$$M\tau=\frac{2\pi}{5}\frac{E\rho^4}{l}\alpha \quad . \quad . \quad . \quad . \quad (2)$$

where ρ is the radius of the steel wires used, E the *c. g. s.* value[2] of the modulus of elasticity of steel.

The moment of the flexural couple is more involved. If p be the distance between vertical planes passing through the bifilar wires, and if f be the horizontal component of the flexural force, then the flexural couple is $M_f=fp$. We have however by geometry, $p=(\lambda\lambda' \sin \alpha)/s$,

[1] Kohlrausch Leitfaden, 1884, p. 167. Maxwell, 1881, vol. ii, p. 108.

[2] Poisson's coefficient is in the following estimate taken at $\frac{1}{4}$: If E' be the current technical modulus referred to the kilogram and square millimeter, $E=E'g\times10^6$.

where s is the sum of the horizontal projections of the wires. We have moreover given us in elastics

$$E=\frac{4}{3}f\frac{l^3}{\pi\rho^4}\frac{1}{\frac{s}{2}},$$

and therefore the couple in question becomes

$$M_f=\frac{3\pi}{8}\frac{\lambda\lambda'\rho^4}{l^3}E\sin\alpha \quad . \quad . \quad . \quad (3)$$

The equations 1, 2, 3 enable us to choose the dimensions of the wire and of the apparatus as well as to select conditions of experiment such that the torsional couple may alone be effective. The following are extremely unfavorable phases of the best available values, in question:
$\lambda=\lambda'<0{\cdot}2^{cm}$; $l>25^{cm}$; $m<250^{g}$; $\alpha<0{\cdot}2^{\circ}$;

$$\rho=0{\cdot}041^{cm};\ E=2\times10^{12}\ (ml^{-1}t^{-2}).$$

In view of the small values of α it is sufficient to compare the coefficients only. We obtain nearly

$$M_b:M_\tau:M_f=1000:280000:20.$$

Hence it appears that in the case of the chosen dimension the most unfavorable effect of the bifilar and flexural couples combined is less than 0·4 per cent of the torsional couple. Moreover the torsional couple becomes more predominant as the angle of deviation, α, increases, so that no serious inaccuracy from the discrepancies here enumerated need be apprehended.

11. When we operate with glass-hard steel, we encounter so many mechanical difficulties, that the conditions postulated in the foregoing analysis can not be immediately assumed. We can not, for instance, adjust the tensions of the two wires precisely to equality. Nor is it easy so to store the permanent torsion that the parallelism of the lines joining the upper and lower points of suspension remains intact. Under these circumstances flexural and bifilar couples may have very different values from the ones accepted, and the moments as a whole, will form a complex aggregate. Although it is improbable that the flexural and bifilar discrepancies will exceed the limits of error investigated, it is none the less desirable to determine them by direct experiment. This can be done with convenience and great accuracy.

Let the water be removed from the jar ILK, and the system be put in vibration around a vertical and in such a way that the angle α remains small. Then the circumstances of motion are given by

$$\frac{4\pi^2K}{Z^2}=\frac{1}{4}\frac{\lambda\lambda'}{l}mg+\tau+\frac{\delta M_f}{\delta\alpha}$$

where K is the moment of inertia of the bifilar body, Z the time of a complete vibration. If we replace the steel wires by threads for which

τ and $\delta M_f / \delta \alpha$ are zero, we may find the value of the bifilar coefficient in terms of the other two. We cite the following typical experiment:

Steel wires: $Z_s = 0{\cdot}025$ sec.; $l = 26^{cm}$; $\lambda < 0{\cdot}1^{cm}$;

Brass capillary wire: $Z_b = 0{\cdot}35$ sec.; $l = 30^{cm}$; $\lambda = 0{\cdot}2^{cm}$; $\lambda' = 0{\cdot}3^{cm}$.

If we reduce the results for capillary brass wire to the l and λ which obtain for steel, we deduce $Z_b = 0{\cdot}40$ sec. Hence the bifilar coefficient is less than 0·4 per cent of the combined torsional and flexural coefficients, in very unfavorable values of the chosen dimensions. This experimental result agrees with the one calculated above.

12. The following static method is better, being exhaustive and final. Let the lower ends of the pair of identical steel wires, A and B, be fastened with the bolt. Let rotation at this end be temporarily checked. Then we may store like degrees of torsion by twisting the upper ends of the wires in the following three ways:

a. Let the wire A be twisted $+360°$ and then fastened to B. Left to itself the upper end of the system will rotate $-180°$ so that the residual torsion of A is $+180°$; of B is $-180°$. The total couple actuating the bifilar body then is of the form $\pm M_b + M_\tau \pm M_f$.

b. Let the wires A and B be twisted $+180°$ and $-180°$ respectively and then fastened together. Left to itself the upper end of the system will not move. The residual torsion is therefore the same as in case *a*; but the total couple here actuating the bifilar body is $M_\tau \pm 0$. This is the case premised in the analysis which introduces this paragraph.

c. Let the wire B be twisted $-360°$ and then fastened to A. Left to itself the upper end will rotate $+180°$, so that the residual torsions on A and B are the same as in cases *a* and *b*; but the total couple which in case of viscous motion actuates the bifilar body has now the form $\mp M_b + M_\tau \mp M_f$.

This is the device: We are able to *commutate*, as it were, the combined flexual and bifilar couples relative to the torsional couple of *fixed* sign. In the results below this test is frequently applied and we will there show that for the chosen dimensions the torsion couple only need be considered.

13. In the case of the tubular apparatus, Fig. 4, the present precautions are at once superfluous. Here each wire is introduced into the tube and compared with the next wire introduced under like circumstances. The tubular apparatus is specially adapted for the investigation of viscous detorsion in its dependence on the applied torsional stress, as well as on time. But the same work may also well be done with the bifilar.

The viscous effect of the relative sections of the wires and allied observations, with a bearing on viscosity proper, can more expediently be made after the experimental data have been communicated. It is convenient to insert a few remarks on the rigidity of efficient parts of the above apparatus here. In the tubular adjustment, if d be the diameter of the wire, d_1 and D_1 the diameters of the tube, if l symbolize the effective

length, T the amount of stored twist, G the rigidity, we have, in view of the equal couples,

$$T\frac{\pi d^4 G}{32l}=T_1\frac{\pi(D^4_1-d^4_1)G_1}{32l_1} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Now in order to make sharp comparisons on the viscosity of solids, in order to investigate its dependence both on time and on stress, the apparatus is to be so adjusted that *like stresses produce like strains* in the substances compared. Hence put $T=T_1$, whence

$$\frac{d^4}{D^4_1-d^4_1}=\frac{G_1 l}{G l_1}=\text{const.}\frac{l}{l_1} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This applies to the bifilar apparatus for $d_1=0$. The equation (2) shows at once how to study viscosity under conditions in which like stresses produce like strains upon like sectional areas of the viscous solids compared.

EXPERIMENTAL DATA.

NOTATION.

14. In Bulletin 14 we used the word "retentiveness" in the restricted German sense to designate magnetic stability, or the property in virtue of which a magnet resists such influences as temperature, percussion, time. The common English use of the term is much broader than this and refers to residual induction[1] in a general way. Fortunately the context of our paper is sufficiently clear and does not admit of serious misapprehension. Inasmuch as measurement of total induction has not yet fallen properly within the scope of our work, we purposely withhold many obvious allusions to magnetic permeability. We moreover retain the term permanent magnetization to denote the magnetic moment *per unit of mass* of a permanently saturated rod, for the sake of uniformity with our earlier notation. Its ratio to magnetic intensity is therefore the density of steel.

To avoid troublesome circumlocution we use the adjective "viscous" with the very broad meaning of "pertaining to viscosity." Such expressions as "viscous phenomena" though not elegant are convenient. Similarly we often speak without confusion of "linear magnetization" where "magnetization of a linear rod" is meant. Cf. § 55.

INTRODUCTORY EXPLANATIONS.

15. The following tables, Nos. 1 to 26, contain results for the viscosity of steel in different states of temper. To these are appended other tables of a miscellaneous kind. For convenience of comparison we insert a little index. The apparatus used in obtaining the data are desig-

[1] Mr. Ewing proposes a new and very elegant extension of the current use of "retentiveness." He defines it as "resistance to any change of magnetic state which (magnets) exhibit whenever the magnetic field in which they are placed suffers any change."—Phil. Trans., vol. 2, 1885, p. 526.

nated by the Roman numerals in the first column. Nos. I to IV are different forms of the bifilar adjustment; No. V is the tubular instrument. The index also contains the numbers of the rods or fibers joined together to make the bifilar couple and gives other information readily understood. Glass and iron fibers are lettered. It is to be remembered that in the steel measurements one of the pair of wires is always glass-hard, the other annealed as specified.

INDEX TO TABLES.

I. EXPERIMENTS PROPER.

Temper of the rod coupled with glass-hard.

Apparatus No.	Annealed at 20°.	Annealed at 100°.	Annealed at 190°.
I.	Table 1, Rods 47, 48.	Table 3, Rods 3, 4. Table 4, Rods 43, 44.	
II.	Table 2, Rods 1, 2.	Table 5, Rods 5, 6. Table 6, Rods 45, 46.	Table 9, Rods 11, 12.
III.		Table 7, Rods 7, 8.	Table 10, Rods 13, 14. Table 11, Rods 19, 20.
IV.		Table 8, Rods 9, 10.	Table 12, Rods 15, 16.
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I.		Table 15, Rods 23, 24.	Table 17, Rods 53, 54 (drawn). Table 18, Rods 27, 28 (soft)
II.	Table 13, Rods 17, 18.	Table 16, Rods 25, 26.	Table 19, Rods 29, 30 (commercial drawn).
III.			Table 20, Rods 31, 32 (commercial annealed).
IV.	Table 14, Rods 21, 22.		Table 21, Rods 33, 34 (annealed from glass-hard).

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Apparatus No.	**Iron (soft). *g*, *d*, *m*, *n*.**	**Brass tube (thick). *e*.**	**Brass tube. (thin). *f*.**
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I.	Table 34, Rods 64, *s* (soft copper).		

EXPERIMENTS PROPER.

16. *Notation.*—In Tables 1 to 26, R denotes the distance between mirror and scale, l the efficient length of the steel (bifilar) wires, λ the distance between the upper and lower points of suspension. T (in degrees) is the stored torsion, imparted to the whole length (30^{cm}) of wire, positively or negatively as specified, whereas $\varphi - \varphi'$ (in radians) is the amount of angular motion (differential detorsion) of the bifilar system due to viscosity, per centimeter of length of the system of two steel wires. Positive values of T and $\varphi - \varphi'$ refer to the same angular direction, and $\varphi - \varphi'$ is arbitrarily put zero (to fix the co-ordinates) at the time one hour after the twist T has been imparted. This is the best conveniently available method for comparing the divers data. Other methods would have compelled us to wait for the subsidence of motion, certainly several months in each case. Moreover, to obtain extreme degrees of accuracy, it is necessary to study viscosity under circumstances of constant temperature, and in a place where the viscous yielding may proceed unaccompanied by tremor or vibratory motion of the apparatus. For these nice experiments we are not now prepared.

The tables furthermore contain the date, the number of hours (h_0) elapsed since the beginning of the experiment, and the arbitrary deflection, N (radians per centimeter of bifilar length), for each of the times specified. The radius of the wires is given under ρ. Finally the sense of the couples actuating the bifilar body is indicated by τ (torsion), b (bifilar), f (flexure).

In practice N is the angle between the normals of the upper and the lower mirror (Fig. 1) divided by the efficient length l, of the wires.

17. The symbol $(\varphi - \varphi')$ has been chosen to indicate the essentially differential character of this variable, as will be fully exhibited. Here it is merely necessary to point out that φ refers to the viscous yielding of one of the counter-twisted wires and φ' to the other. In succeeding chapters we shall usually replace T by the rate of twist $\tau = T / l$. In the present chapter, since there is no means of measuring the total viscous yield during the interval of observation, T is the initial value 180° given by the method of adjustment, § 12. As the experiment continues, T is reduced in value.

It is to be remembered that one of the two wires is always glass-hard.

18. *Rods annealed* at 25° and at 100°.—The data obtained are given in Tables 1 to 8.

TABLE 1.—APPARATUS I.

$R=217^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 47, glass-hard, $T=-180°$; No. 48, glass-hard, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 21, 6h 08m	(*)	0·00	(*)	Aug. 25, 9h 05m	0·615	91·92	0·156
6 21	0·438	0·22	−0·030	7 01	0·682		
7 08	0·468	1·00	+0·000	26, 9h 10m	0·653	114·52	0·194
22, 9h 57m	0·543	15·82	0·075	4 08	0·670		
5 58	0·552	23·83	0·084	27, 9h 11m	0·695	140·26	0·237
6 54	0·555	24·77	0·087	7 36	0·714		
23, 9h 08m	0·568	39·00	0·100	28, 9h 21m	0·734	164·00	0·276
12 31	0·572	42·38	0·104	6 55	0·755		
5 37	0·577	47·48	0·109	29, 10h 12m	0·780	188·11	0·318
24, 9h 17m	0·588	67·12	0·126	6 17	0.792		
5 13	0·600						

* Adjusted $\tau-b-f$.

TABLE 2.—APPARATUS II.

$R=203^{cm}$; $l=26^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 1, glass-hard, $T=+180°$; No. 2, glass-hard, $T=-180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 11, 4h 30m	(*)	0 00	(*)	June 12, 8h 35m	1·920	16·08	0·015
5 00	1·896	0.50	−0 009	9 25	1·922	16·92	0·017
5 30	1·905	1·00	±0·000	10 10	1·922	17 67	0·017
6 15	1·909	1·75	+0·004	1 5	1·926	20 58	0·021
7 00	1 910	2·50	0·005	2 20	1·926	21·83	0·021
7 33	1·913	3·06	0·008	5 00	1·926	24·50	0·021
				5 50	1·926	25·33	0·021
				8 30	1·926	28 00	0·021
				13, 8h 30m	1·926	40·00	0.021

* Adjusted $\tau-b-f$.

TABLE 3.—APPARATUS I.

$R=209^{cm}$; $l=27^{cm}$; $\lambda<0.2^{cm}$. Rods: No. 3, glass-hard, $T=-180°$; No. 4, annealed at 100°, 10h, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 24, 8h 30m	(*)	0·00	(*)	June 26, 8h 23m	0·755	47·88	0·561
9 00	0·139	0·50	−0·055	12 04	0·767	51·57	0·573
9 30	0·194	1·00	±0·000	3 17	0·778	54·78	0·584
10 56	0·277	2·43	+0·083	6 50	0·792	58·38	0·598
11 49	0·312	3·32	0·118	27, 8h 50m	0·825	72·33	0·631
12 37	0·338	4·12	0 144	3 04	0·834	78·57	0·640
1 52	0·373	5·37	0·179	28, 8h 09m	0·857	95·65	0·663
3 15	0·401	6·75	0·207	11 29	0·857	98·98	0·663
4 01	0·418	7·52	0.224	5 22	0·859	104·87	0·665
4 55	0·433	8·42	0·239	29, 8h 07m	0·864	118·63	0·670
6 5	0·453	9·58	0·259				
25, 8h 41m	0·619	24·18	0·425				
11 35	0·640	27·08	0·446				
5 25	0·682	32·92	0 488				
6 58	0·692	34·47	0·498				

* Adjusted $\tau-b-f$.

TABLE 4.—APPARATUS I.

$R=217^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 43, glass-hard, $T=-180°$; No. 44, annealed at 100°, 9h, $T=+180°$. $2\rho=0{\cdot}082$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 8, 5h 00m	(*)	0·00	(*)	Aug. 14, 9h 11m	—0·447	140·19	1·618
5 17	1·265	0·28	—0·125	5 12	—0·509		
6 17	1·127	1·28	+0·013	15, 1h 34m	—0·635	167·07	1·790
7 33	1·043	2·56	+0·097	6 35	—0·664		
9, 9h 05m	0·736	16·08	0·404	16, 1h 27m	—0·755	191·18	1·909
11 56	0·686	18·93	0·454	6 55	—0·783		
1 06	0·664	20·10	0·476	17, 9h 22m	—0·858	213·15	2·028
7 05	0·579	26·08	0·561	6 55	—0·918		
10, 10h 02m	0·427	41·03	0·713	18, 9h 15m	—0·984	236·36	2·139
1 19	0·368	44·32	0·752	5 29	—1·015		
6 20	0·333	49·33	0·807	19, 9h 03m	—1·066	260·82	2·220
11, 10h 06m	0·184	69·15	1·001	6 35	—1·094		
1 15	0·147			20, 9h 16m	—1·136	285·00	2·289
7 06	0·095			6 44	—1·162		
12, 9h 22m	—0·042	92·43	1·220	21, 9h 07m	—1·196	304·12	2·336
5 30	—0·117						
13, 9h 09m	—0·245	116·10	1·422				
1 28	—0·285						
4 41	—0·316						

* Adjusted $\tau+b+f$.

TABLE 5.—APPARATUS II.

$R=203^{cm}$; $l=26^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 5, glass-hard, $T=-180°$; No. 6, annealed at 100°, 9h, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 13, 9h 15m	(*)	0 00	(*)	June 14, 9h 00m	2·393	23 75	0·486
10 15	1·907	1·00	0·000	10 30	2·401	25·25	0·494
11 15	2·031	2·00	0·124	1 3	2·407	27·80	0·500
12 05	2·100	2 83	0·193	2 6	2·409	28·85	0·502
1 25	2·162	4·17	0·255	3 50	2·409	30·58	0·502
3 16	2·247	6·02	0·340	5 27	2·412	32·20	0·505
5 05	2·296	7·83	0·389	†6 53	2·412	33·60	0·505
6 50	2·345	9·58	0·438				
7 30	2·358	10·25	0·451				

* Adjusted, $\tau-b-f$. † Subsequent movement apparently retrograde.

TABLE 6.—APPARATUS II.

$R=202^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 45, glass-hard, $T=-180°$; No. 46, annealed at 100°, 10h, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 8, 6h 10m	(*)	0·00	(*)	Aug. 14, 9h 11m	0·440	139·03	1·020
6 19	1·502	0·15	—0 062	5 12	0·399		
7 32	1·422	1·37	+0 018	15, 1h 34m	0·316	165·91	1·133
9, 9h 55m	1·195	15 75	0·245	6 35	0 298		
12 31	1·169	18·35	0·271	16, 1h 27m	0·234	190·02	1·218
7 52	1·098	25·70	0·342	6 55	0·211		
10, 10h 02m	1·007	39·87	0·433	17, 9h 22m	0·163	211·98	1·299
1 19	0·993	43·15	0·447	6 55	0·119		
6 19	0·948	48·15	0·192	18, 9h 15m	0·070	235·20	1·382
11, 10h 45m	0·853	68·19	0·615	5 29	0·046		
1 14	0·833			19, 9h 03m	0·007	259·65	1·440
7 05	0·789			6 35	—0·008		
12, 9h 22m	0·709	91·26	0·756	20, 9h 16m	—0·040	283·83	1·488
5 30	0·658			6 44	—0·056		
13, 9h 09m	0·576	114·93	0·891				
1 28	0·544						
4 41	0·526						

* Adjusted, $\tau+b+f$.

TABLE 7.—APPARATUS III.

$R=400^{mm}$; $l=27^{mm}$; $\lambda<0.2^{mm}$. Rods: No. 7, glass-hard, $T=-180°$; No. 8, annealed at 100°, 10h, $T=+180°$. $2\rho=0{\cdot}082^{mm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 1, 12h 40m	(*)	0·00	(*)	July 6, 8h 40m	1·890	120·61	1·137
1 20	3·122	0 67	−0·128	1 53	1·854		
2 45	2·994	2·08	±0·000	5 16	1·826		
3 25	2 956	2·76	+0·038	7, 8h 53m	1·730	144·55	1·300
4 37	2·903	3·95	0·091	1 30	1·691		
5 39	2·869	4·98	0·125	5 16	1·660		
6 49	2·832	6·32	0·162	8, 9h 16m	1·547	168·59	1·485
2, 9h 22m	2·627	20·70	0·367	12 43	1,515		
1 46	2·578	25·10	0·416	5 48	1·465		
5 11	2·554	28·52	0·440	9, 8h 35m	1·366	192·02	1·657
3, 8h 20m	2·435	43 67	0·559	12 11	1·339		
12 14	2·397	47·57	0·597	5 18	1·307		
6 30	2·331	53·83	0·663	10, 8h 07m	1·225	215·87	1·798
4, 9h 47m	2·238	73·10	0 809	12 09	1·200		
12 09	2·208			5 20	1·162		
3 08	2·183			11, 9h 08m	1·080	236·47	1·914
6 00	2·153						
5, 8h 40m	2·061	95·80	0·965				
12 00	2·033						
4 44	1·992						

* Adjusted, $\tau+b+f$.

TABLE 8.—APPARATUS IV.

$R=308^{mm}$; $l=28^{mm}$; $\lambda<0{\cdot}2^{mm}$. Rods: No. 9, glass-hard, $T=-180°$; No. 10, annealed at 100°, 10h $T=+180°$. $2\rho=0.082^{mm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 1, 1h 40m	(*)	0·00	(*)	July 5, 8h 41m	1·876	94·81	0·718
2 46	1·185	1·10	0·000	12 00	1·899		
3 26	1·213	1·77	0·028	4 45	1·935		
4 39	1·246	2·82	0·061	6, 8h 42m	2·027	119·63	0·874
5 40	1·265	4·00	0·080	1 54	2·063		
7 00	1·290	5.33	0·105	5 17	2·088		
2, 9h 22m	1·420	19·72	0·236	7, 8h 54m	2·185	143·58	1·034
1 48	1·459	24·13	0·274	1 32	2·222		
5 12	1·482	28·53	0·297	5 18	2·249		
3, 8h 22m	1·577	42·70	0·392	8, 9h 18m	2·362	167·61	1·206
12 15	1·605	46·58	0·420	12 43	2·385		
6 30	1·641	52·83	0·456	5 49	2·427		
4, 9h 49m	1·729	72·12	0 574	9, 8h 37m	2·524	191·04	1·360
12 10	1·747			12 11	2·547		
3 09	1·770			5 19	2·581		
6 01	1·791			10, 8h 07m	2·655	210·45	1·470

* Adjusted. $\tau-b-f$.

The data of these tables are graphically given in the accompanying Fig. 8, deformation ($\varphi-\varphi'$), as ordinate, time in hours as abscissæ. Some irregularity of behavior is visible, due to the fact to be further indicated in chapters II and III, that the viscosity of glass-hard steel can be enormously reduced by twisting. Indeed a glass-hard wire twisted back and forth as far as maximum viscosity shows about the same value of that quality as a rod annealed at 100° to the maximum of permanent hardness. In their mean relations, however, the results of this figure are satisfactory and easily comparable with the new results now to be adduced.

The ordinates increase in the order of greater viscosity so that the abscissæ are glass-hard wires.

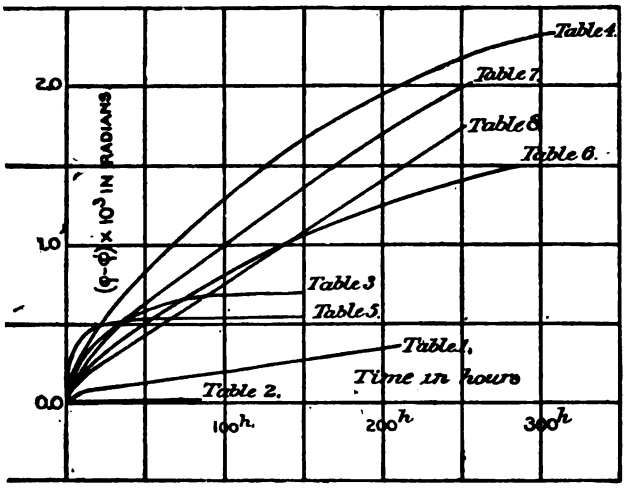

FIG. 8.—Viscous deformation of steel annealed at 20° and at 100°, compared with glass-hard steel.

19. *Rods annealed at* 190°.—The data obtained are as follows:

TABLE 9—APPARATUS II.

$R=200^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 11, glass-hard, $T=-180°$; No 12, annealed at 190°, 2^h; $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times 10^3$	h_0	$(\phi-\phi')\times 10^3$	Date.	$N\times 10^3$	h_0	$(\phi-\phi')\times 10^3$
July 1, $4^h\ 00^m$	(*)	0·00	(*)	July 2, $9^h\ 20^m$	2·215	17·33	0.625
$4\ 35$	2·913	0·58	−0·073	$1\ 45$	2·133	21·75	0·707
$5\ 36$	2·767	1·60	+0·073	$5\ 09$	2·080	25·15	0·760
$6\ 58$	2·655	2·97	0·185	July 3, $8^h\ 19^m$	1·891	40·32	0.949
				$12\ 12$	1·843	44·20	0·997
				$6\ 28$	1.757	50·47	1·803

* Adjusted, $\tau+b+f$.

TABLE 10—APPARATUS III.

$R=370^{cm}$; $l=26^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 13, glass-hard, $T=-180°$; No. 14, annealed at 190°, 1h; $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 14, 12h 30m	(*)	0·00	(*)	June 21, 8h 22m	3·732	169·91	2·692
1 10	1·025	0·67	−0·065	12 15	3·763		
2 05	1·198	1·58	+0·108	5 44	3·810		
3 51	1·402	3·35	0.312	†7 17	3·823		
4 21	1·448	3·85	0·358	22, 9h 10m	3·913	193·38	2·856
5 29	1·525	4·98	0·435	1 18	3·943		
6 55	1·606	6·42	0·516	2 20	3·948		
7 51	1·648	7·35	0.558	6 42	3·980		
15, 9h 04m	2·022	20·57	0·932	23, 8h 30m	4·056	214·86	2·971
10 00	2·042	21·50	0·952	12 43	4·077		
11 15	2·073	22 75	0·983	5 42	4·111		
1 10	2·121	24·67	1·031	24, 9h 02m	4·197	240·38	3·132
2 58	2·165	26·47	1·075	12 39	4·222		
4 17	2·195	27.78	1·105	4 58	4·248		
5 41	2·223	29·18	1·133	25, 8h 44m	4·335	264·13	3·266
6 18	2·233	29·80	1·143	11 38	4·351		
16, 8h 00m	2·467	48·26	1·460	†5 31	4·383		
9 32	2·492			26, 8h 29m	4·448	289·18	3·385
1 07	2·556			12 10	4·467		
3 19	2·597			3 12	4·483		
5 50	2·638			6 52	4·504		
17, 8h 34m	2·861	73·43	1·878	27, 8h 52m	4·575	311·49	3·502
10 29	2·899			3 06	4·609		
12 43	2·942			28, 8h 11m	4·699	335·87	3·631
3 35	2·995			11 30	4·720		
5 29	3·043			5 25	4·744		
6 45	3·066			29, 8h 11m	4·811	361·44	3·754
18,11h 45m	3·236	99·02	2·181	3 46	4·854		
4 39	3·283			5 52	4·866		
†6 09	3·293			30, 8h 53m	4·943	384·41	3·872
19, 9h 07m	3·410	120·92	2·346	12 26	4·962		
12 19	3·432			5 25	4·982		
2 25	3·445			July 1, 8h 47m	5·028	404·28	5·028
5 50	3·458						
20, 8h 53m	3·567	145·23	2·515				
10 53	3·581						
3 26	3·622						
7 44	3·652						

* Adjusted, $\tau-b-f$. † Readjusted after this observation.

TABLE 11—APPARATUS III.

$R=400^{cm}$; $l27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 19, glass-hard, $T=-180°$; No. 20, annealed at 190°, 1h; $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 11, 3h 20m	(*)	0·00	(*)	July 15, 10h 46m	1·491	94·27	2·013
4 10	−0·037	0·83	−0·037	4 26	1·548		
4 20	±0·000	1·00	±0·000	16, 9h 18m	1·695	118·32	2·232
5 22	+0·161	2·03	+0·161	1 44	1·740		
7 00	0·329	3·67	0·329	5 55	1·760		
12, 7h 37m	0·913	16 28	0·913	17, 8h 47m	1·899	141·90	2·438
7 55	†	16·58	†	12 53	1·940		
9 02	0·466	17·70	0·960	6 02	1·992		
10 55	0·523	19·58	1·017	18, 8h 44m	2·096	164·25	2 617
5 27	0·696	26·12	1·190	2 26	2·151		
13, 8h 29m	0·952	41·15	1·446	19, 9h 39m	2 304	189·73	2·829
12 29	0·999	45·15	1·493	12 20	3·331		
5 08	1·061	49·80	1·555	5 12	2·371		
14, 8h 54m	1·220	69·49	1·765				
12 51	1·270						
4 41	1·314						

* Adjusted, $\tau+b+f$. † Adjusted, $\tau-b-f$.

TABLE 12—APPARATUS IV.

$R = 300^{cm}$; $l = 27^{cm}$; $\lambda < 0{\cdot}2^{cm}$. Rods, No. 15, glass-hard, $T = -30°$; No. 16, annealed at 190°, 1^h; $T = +180°$. $2\rho = 0{\cdot}082^{cm}$.

Date.	$N \times 10^3$	h_0	$(\phi - \phi') \times 10^3$	Date.	$N \times 10^3$	h_0	$(\varphi - \phi') \times 10^3$
July 11, $4^h\ 25^m$	(*)	0·00	(*)	July 16, $9^h\ 19^m$	1·849	117·26	1·919
$4\ 42$	−0·210	0·28	−0·175	$1\ 45$	1·885		
$4\ 55$	−0·143	0·50	−0·108	$5\ 58$	1·917		
$5\ 25$	−0·035	1·00	±0·000	17, $8^h\ 49^m$	2·022	140·84	2·093
$7\ 00$	+0·153	2·58	+0·188	$12\ 54$	2·052		
12, $7^h\ 38^m$	0·685	15·22	0·720	$6\ 03$	2·099		
$5\ 28$	0·937	25 05	0·972	18, $8^h\ 45^m$	2·198	163·35	2·256
13, $8^h\ 29^m$	1·179	40·07	1·214	$2\ 47$	2·243		
$12\ 29$	1·222	44·07	1·257	19, $9^h\ 40^m$	2·378	188 66	2·444
$5\ 09$	1·280	48 73	1·315	$12\ 21$	2·419		
14, $8^h\ 54^m$	1·434	68·10	1·508	$5\ 13$	2·429		
$12\ 52$	1·473			20, $8^h\ 32^m$	2·517	209·68	2·562
$4\ 42$	1·512			$11\ 40$	2·538		
15, $10^h\ 47^m$	1·670	93·20	1·730				
$4\ 26$	1·720						

* Adjusted, $\tau - b - f$.

The results of these tables are given in Fig. 9, in the way already indicated in Fig. 8. The agreement here is much more uniform than in the former case. Rods show pronounced increase of viscosity.

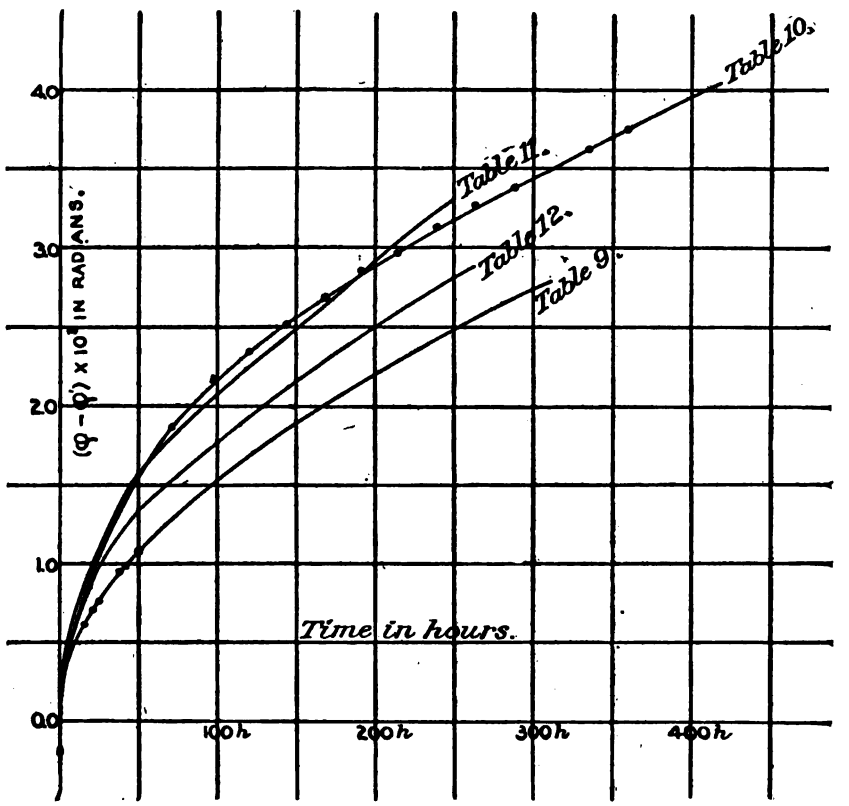

FIG. 9.—Viscous deformation of steel annealed at 190°, compared with glass-hard steel.

20. ***Rods annealed at*** **360°.** The data obtained are as follows:

TABLE 13.—APPARATUS II.

$R = 200^{cm}$; $l = 27^{cm}$; $\lambda < 0{\cdot}2^{cm}$. Rods: No. 17, glass-hard, $T = -180°$; No. 18, annealed at 350°, 1^h, $T = +180°$. $2\rho = 0{\cdot}082^{cm}$.

Date.	$N \times 10^8$	h_0	$(\phi - \phi') \times 10^8$	Date.	$N \times 10^8$	h_0	$(\phi - \phi') \times 10^8$
July 4, $10^h\ 35^m$	(*)	0·00	(*)	July 10, $8^h\ 05^m$	0·545	145·93	3·092
10 53	−2·767	0·30	−0·267	12 08	0·589		
12 08	−2·457	1·55	+0·043	5 19	0·643		
3 07	−2·118	4·53	0·382	11, $9^h\ 08^m$	0·797	171·67	3·348
5 59	−1·929	7·40	0·570	11 34	0·821		
5, $8^h\ 39^m$	−1·423	22.07	1·076	5 21	0·881		
11 59	−1·318	25·40	1·181	6 59	0·892		
5 43	−1·187	31·13	1·312	12, $7^h\ 36^m$	0·993	193·93	3·533
6, $8^h\ 40^m$	−0·882	46 08	1·617	5 26	1·072		
1 52	−0·773	51·28	1·726	13, $8^h\ 27^m$	1·163	218·10	3·686
5 15	−0·703	54·67	1·796	12 27	1·180		
7, $8^h\ 50^m$	−0·455	74·59	2·127	5 08	1·215		
1 26	−0·367			14, $8^h\ 53^m$	1·299	242·20	3 823
5 15	−0·295			12 48	1·323		
8, $9^h\ 15^m$	−0·056	98·66	2·513	4 40	1·348		
12 42	+0·007			15, $10^h\ 45^m$	1·446	267·00	3·965
5 47	0·089			4 25	1·483		
9, $8^h\ 34^m$	0·274	122·09	2·826	16, $9^h\ 17^m$	1·565	286·70	4·065
12 10	0·321						
5 17	0·383						

* Adjusted $\tau - b - f$.

TABLE 14.—APPARATUS IV.

$R = 316^{cm}$; $l = 26^{cm}$; $\lambda < 0{\cdot}2^{cm}$. Rods: No. 21, glass-hard, $T = -180°$; No. 22, annealed at 360°, 1^h, $T = +180°$. $2\rho = 0{\cdot}082^{cm}$.

Date.	$N \times 10^8$	h_0	$(\phi - \phi') \times 10^8$	Date.	$N \times 10^8$	h_0	$(\phi - \phi') \times 10^8$
June 14, $2^h\ 45^m$	(*)	0·00	(*)	June 21, $8^h\ 23^m$	4·374	167·66	3·290
3 52	1·155	1·12	0·025	12 15	4·403		
4 22	1·250	1·62	0·120	5 45	4·447		
5 30	1·415	2·75	0·285	7 16	4·456		
6 55	1·558	4·17	0·428	22, $9^h\ 11^m$	4·541	191·61	3 434
7 53	1·632	5·13	0·502	1 19	4·558		
15, $9^h\ 05^m$	2·198	18.33	1·068	4 13	4·573		
†10 00	2·231	19·25	1·101	6 43	4·583		
11 16	2·273	20·52	1·143	23, $8^h\ 30^m$	4·666	214·22	3·569
1 11	2·340	22·43	1·210	12 43	4·699		
3 00	2·400	24·25	1·270	5 42	4·732		
4 16	2·442	25·57	1 312	24, $9^h\ 03^m$	4·829	238·15	3 722
5 42	2·478	26·95	1·348	12 40	4·853		
6 19	2·490	27·57	1·360	4 59	4·873		
16, $8^h\ 02^m$	2·802	46·03	1·785	25, $8^h\ 45^m$	4·973	261·88	3·875
9 33	2·837			11 39	4·997		
1 09	2·928			5 30	5·044		
3 20	2·978			26, $8^h\ 30^m$	5·143	286·87	4·048
5 50	3·028			†1 28	5·177		
17, $8^h\ 35^m$	3·302	71·19	2·296	6 53	5·213		
10 30	3·349			27, $8^h\ 53^m$	5·303	309·25	4·196
12 44	3·405			3 07	5·350		
3 36	3·465			28, $8^h\ 13^m$	5·450	333·64	4·346
5 30	3·503			11 31	5·471		
6 45	3·531			5 26	5·508		
18, $8^h\ 53^m$	3·741	95·12	2·667	29, $8^h\ 12^m$	5·595	359·19	4·505
11 45	3·770			3 45	5·647		
4 40	3·829			5 53	5·662		
†6 10	2·850			30, $8^h\ 54^m$	5·740	382·18	4·629
19, $9^h\ 09^m$	4·000	118·69	2·904	12 27	5·757		
12 19	4·026			5 26	5·780		
2 27	4·037			July 1, $8^h\ 48^m$	5·848	402·05	5·848
5 51	4·071						
20, $8^h\ 54^m$	4·193	143·01	3·105				
10 59	4·211						
3 25	4·250						
7 45	4·286						

* *Adjusted* $\tau - b - f$. † Readjusted.

Figure 10 contains a graphic representation of the preceding tables on the plan already described (cf. Table 8).

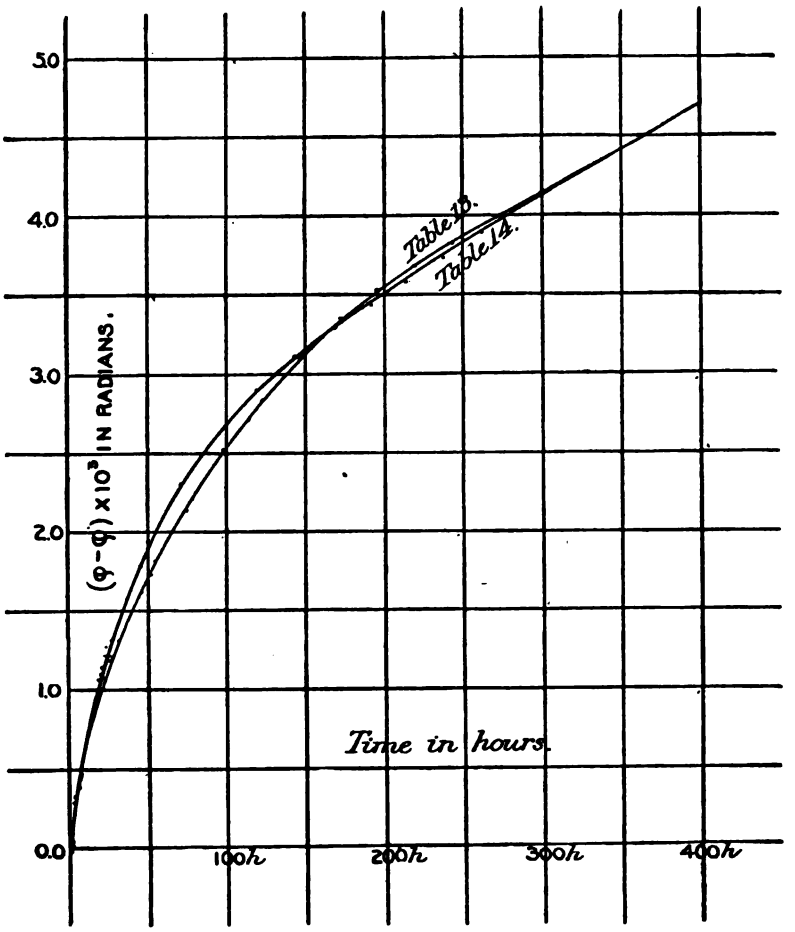

FIG. 10.—Viscous deformation of steel annealed at 360°, compared with glass-hard steel.

21. ***Rods annealed at*** **450°.—The data in hand are as follows:**

TABLE 15.—APPARATUS I.

$R=217^{cm}$; $\lambda=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 23, glass-hard, $T=-180°$; No. 24, annealed at 450°, 1^h, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 21, 2^h 50^m	(*)	0·00	(*)	July 29, 8^h 56^m	−0·673	189·80	3·814
3 17	3·276	0·45	−0·176	12 36	−0·714		
4 44	2·901	1·90	+0·198	4 22	−0·758		
5 21	2·805	2·52	0·294	30, 8^h 52^m	−0·937	213·85	4·085
6 13	2·698	3·38	0·401	1 05	−0·991		
22, 8^h 40^m	1·924	17·83	1·175	4 07	−1·030		
11 58	1·798	21·13	1·301	31, 9^h 28^m	−1·210	237·82	4·345
5 30	1·606	26·67	1·493	12 36	−1·249		
7 10	1·552	28·33	1·547	3 55	−1.281		
23, 7^h 49^m	1·307	40·98	1·792	Aug. 2, 9^h 38^m	−1·639	286 13	4·768
12 30	1·141	45·67	1 958	1 11	−1·672		
3 31	1·072	48 68	2·027	4 05	−1·696		
24, 9^h 13^m	0·769	69·91	2·393	3, 9^h 38^m	−1 807	310·22	4·926
12 52	0·702			1 14	−1·826		
4 10	0·647			4 18	−1·844		
26, 8^h 53^m	0·126	117·40	3·019	4, 1^h 31^m	−1 947	336 12	5·055
12 07	0·081			4 23	−1·962		
3 42	0 033			5, 1^h 36^m	−2·052	360·67	5·162
27, 8^h 49^m	−0·146	141·60	3·290	5 25	−2·073		
12 26	−0·193			6, 9^h 12^m	−2 139	382·48	5·257
4 04	−0·235			5 26	−2·175		
28, 9^h 11^m	−0·423	166·03	3·564	7, 9^h 15^m	−2·225	407·13	5·346
1 07	−0·468			6 41	−2·268		
4 17	−0·503						

* Adjusted $\tau+b+f$.

TABLE 16.—APPARATUS II.

$R=198^{cm}$; $\lambda=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 25, glass-hard, $T=-180°$; No. 26, annealed at 450°, 1^h, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 15, 12^h 50^m	(*)	0·00	(*)	June 21, 8^h 20^m	5·364	145·55	3·177
1 07	1·968	0·28	−0·282	12 15	5·401		
1 15	2·046	0·42	−0·204	†5 40	5·466		
1 30	2·152	0·67	−0·098	7 19	5·478		
1 45	2·239	0·92	−0·011	22, 9^h 08^m	5·573	169·47	3·355
2 55	2·475	2·08	+0 225	1 16	5·597		
4 15	2·648	3·42	0·398	4 10	5·617		
5 39	2·776	4·82	0·526	6 40	5·632		
6 17	2 825	5·45	0·575	23, 8^h 27^m	5·717	192·10	3·499
16, 7^h 56^m	3·447	19·10	1·197	12 40	5·748		
9 30	3·506	20·67	1·256	5 41	5·781		
1 06	3·632	24.27	1·382	24, 9^h 00^m	5·880	216·01	3·660
3 17	3·703	26·45	1·453	12 37	5·909		
5 49	3·780	28·98	1·530	4 55	5·941		
17, 8^h 33^m	4·134	49·06	2·035	25, 8^h 42^m	6·045	239 76	3·820
10 26	4·191			11 36	6·068		
12 41	4·258			5 28	6 111		
3 31	4·337			26, 8^h 27^m	6·206	264·29	3·989
5 26	4·378			12 05	6·227		
6 44	4·410			6 05	6·283		
18, 8^h 48^m	4·656	72·98	2·471	27, 8^h 51^m	6·367	287·11	4·140
11 43	4·690			3 02	6·412		
4 38	4·759			28, 8^h 08^m	6·516	311·51	4·326
6 07	4·778			11 29	6·535		
19, 9^h 05^m	4·953	96·53	2·741	5 24	6·678		
12 10	4·982			29, 8^h 09^m	6·662	337·07	4·451
2 23	4·998			3 43	6 714		
5 50	5·031			5 50	6·728		
20, 8^h 12^m	5·170	120·71	2·963	30, 8^h 52^m	6·811	350·08	4·577
10 52	5·179			12 29	6·825		
3 24	5·232			5 24	6·845		
7 42	5·270			July 1, 8^h 39^m	6·910	379·82	4·660

* *Adjusted,* $\tau-b-f$. † Readjusted.

The results of these tables are given in the Chart Fig. 11 on the plan already clearly indicated. The ordinates increase in the order of greater viscosity.

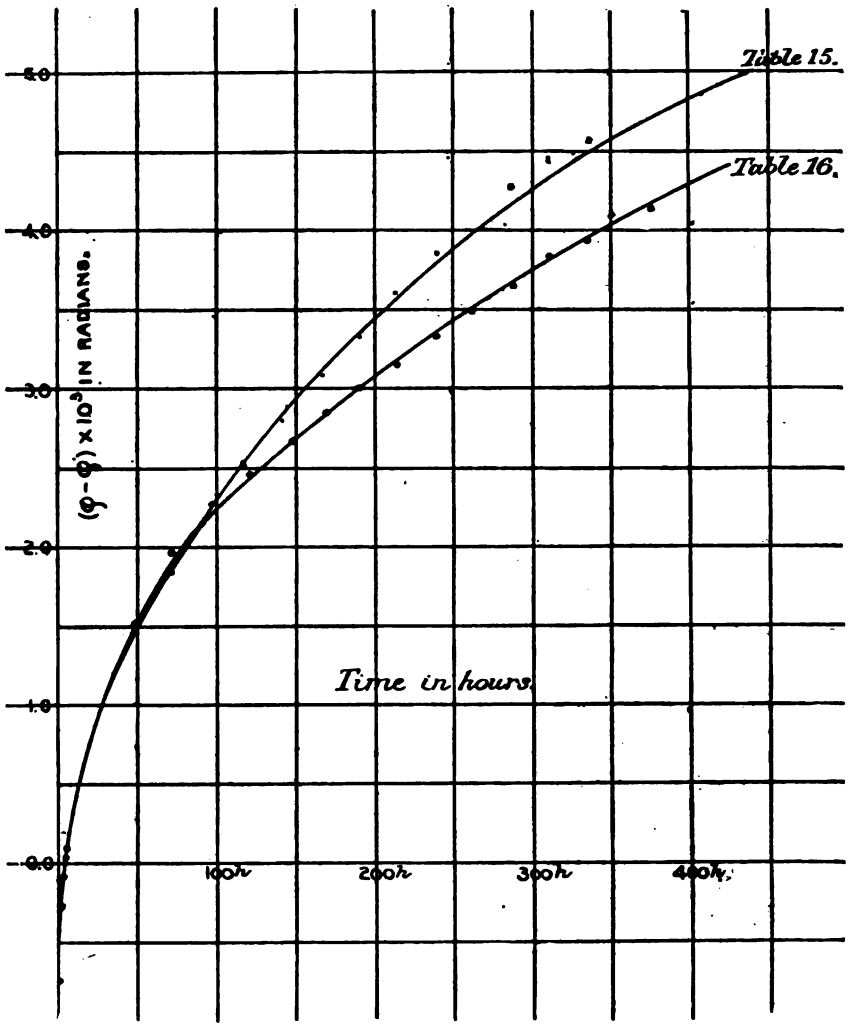

FIG. 11.—Viscous deformation of steel annealed at 450°, compared with glass-hard steel.

22. ***Soft rods.***—The data in hand are as follows:

TABLE 17.—APPARATUS I.

$b=27^{cm}$; $R=202^{cm}$. Rods: No. 53, steel glass-hard; $2\rho=0{\cdot}082^{cm}$; $T=-180°$; No. 54, steel drawn; $2\rho=0{\cdot}082^{cm}$; $T=+180°$.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Remarks.
Sept. 28, 2h 00m	0·00	.....	0·00	.....	Adjusted.
2 10	0·17	0·789	0·17	—0·239	
2 30	0·50	0·661	0·50	—0·111	
3 35	1·60	0·486	1·60	+0·064	
8 00	6·00	+0·171	6·00	+0·379	
29, 10 18	20·30	—0·206	20·30	+0·756	

TABLE 18.—APPARATUS 1.

$R=215^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 27, glass-hard, $T=-180°$; No. 28, soft, $T=+180°$. $2\rho=0{\cdot}082$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 9, 2h 30m	(*)	0·00	(*)	June 14, 9h 04m	4·736		
3 10	1·652	0·67	—0·118	10 30	4·757	120·33	3·046
3 13	1·677	0·71	—0·093	1 00	4·796		
3 21	1·730	0·85	—0·040	2 06	4·813		
3 47	1·860	1·28	+0·090	3 50	4·836		
4 09	1·910	1·50	0·140	5 27	4·853		
4 10	1·940	1·67	0·170	6 52	4·866		
4 32	2·004	2·03	0·234	7 50	4·873		
5 15	2·102	2·75	0·332	15, 9h 00m	4·990	143·30	3·272
5 35	2·140	3·08	†0·370	10 00	4·998		
6 09	2·185	3·50	0·415	11 15	5·015		
6 15	2·210	3·75	0·440	1 05	5·037		
10, 8h 50m	2·938	20·09	1·227	2 55	5·060		
9 35	2·964			4 15	5·071		
9 55	2·973			5 38	5·082		
10 15	2·985			6 15	5·086		
10 45	3·002			16, 7h 58m	5·205	166·22	3·488
11 20	3·023			9 30	5·223		
11 45	3·038			1 05	5·265		
12 17	3·056			3 15	5·285		
10, 1h 30m	3·100	26·64	1·448	5 48	5·310		
2 15	3·128			17, 8h 30m	5·455	191·54	3·758
3 05	3·153			10 26	5·485		
4 00	3·191			12 40	5·520		
4 40	3·214			3 30	5·550		
5 25	3·238			5 27	5·570		
6 25	3·265			7 43	5·590		
†7 40	3·287			18, 8h 46m	5·705	215·31	3·970
8 05	3·296			11 43	5·720		
8 20	3·304			4 37	5·760		
11, 8h 06m	3·512	47·34	1·895	6 08	5·775		
9 28	3·571			19, 9h 04m	5·880	238·52	4·125
10 21	3·588			12 09	5·890		
10 45	3·598			5 50	5·915		
11 45	3·617			20, 8h 50m	6·010	263·18	4·272
12 11	3·628			10 50	6·023		
2 30	3·680			3 23	6·055		
3 48	3·709			7 40	6·080		
4 50	3·733			21, 8h 20m	6·140	287·88	4·408
5 50	3·753			12 15	6·160		
7 00	3·777			5 38	6·200		
7 35	3·787			7 19	6·210		
12, 8h 37m	3·989	71·44	2·318	22, 9h 07m	6·270	311·80	4·525
9 25	4·005			1 16	6·290		
10 10	4·017			4 09	6·305		
1 05	4·076			6 40	6·315		
2 55	4·108			23, 8h 28m	6·375	334·44	4·633
4 58	4·146			12 40	6·405		
5 50	4·162			5 40	6·430		
8 30	4·202						
13, 8h 40m	4·376	95·89	2·702				
10 15	4·405						
12 06	4·436						
1 25	4·458						
3 16	4·485						
5 07	4·517						
6 50	4·545						
7 30	4·556						

* *Adjusted.* † Readjusted.

TABLE 19.—APPARATUS II.

$R = 202^{cm}$; $l = 28^{cm}$; $\lambda < 0{\cdot}2^{cm}$. Rods: No. 29, glass-hard, $T = -180°$; No. 30, commercial, drawn, $T = +180°$. $2\rho = 0{\cdot}082^{cm}$.

Date.	$N \times 10^3$	h_0	$(\phi - \phi') \times 10^3$	Date.	$N \times 10^3$	h_0	$(\phi - \phi') \times 10^3$
July 21, 10h 45m	(*)	0.00	(*)	July 29, 8h 56m	−0·709	193·90	3·012
11 50	2·263	1·08	0·000	12 39	−0·749		
12 18	2·206	1·55	0 057	4 23	−0·788		
2 03	2·045	3·30	0·218	30, 8h 54m	−0·957	217·96	3·269
3 52	1·926	5·12	0·337	1 06	−1·010		
5 22	1·847	6 62	0·416	4 07	−1·050		
22, 8h 40m	1·416	21·92	0·847	31, 9h 42m	−1·230	242·01	3·526
11 58	1·341	25·22	0·922	12 37	−1·263		
5 31	1·217	30·77	1·046	3 57	−1·297		
7 44	1·187	32·98	1·076	Aug. 2, 9h 39m	−1·644	290·23	3·934
23, 7h 50m	0·994	45 08	1·279	1 12	−1·677		
12 32	0·896	49·78	1·367	4 06	−1·693		
3 33	0·851	52·80	1·412	3, 9h 40m	−1·780	314·33	4·049
24, 9h 16m	0·624	74.03	1·737	1 15	−1·784		
12 53	0·499			4 19	−1·793		
4 12	0·456			4, 1h 32m	−1·872	340·22	4·139
26, 8h 55m	−0·025	121·53	2·292	4 24	−1·880		
12 08	−0·011			5, 1h 37m	−1·965	364·77	4·237
3 47	−0·051			5 25	−1 982		
27, 8h 51m	−0·211	145·71	2·516	6, 9h 13m	−2·044	386·59	4·324
12 27	−0·255			5 27	−2·078		
4 05	−0 293			7, 9h 17m	−2·133	411·24	4·412
28, 9h 20m	−0·487	170·18	2·781	6 42	−2 165		
1 09	−0·517						
4 18	−0·550						

* Adjusted, $\tau + b + f$.

TABLE 20.—APPARATUS III.

$R = 370^{cm}$; $l = 27^{cm}$; $\lambda < 0{\cdot}2^{cm}$. Rods: No. 31, glass-hard, $T = -180°$; No. 32, commercial, softened, $T = +180°$. $2\rho = 0{\cdot}082^{cm}$.

Date.	$N \times 10^3$	h_0	$(\phi - \phi') \times 10^3$	Date.	$N \times 10^3$	h_0	$(\phi - \phi') \times 10^3$
July 22, 9h 00m	(*)	0·00	(*)	July 27, 8h 54m	−2·305	123·51	3·055
9 08	0·949	0·13	−0·249	12 30	−2·356		
11 59	0·331	2·98	+0 368	4 08	−2·404		
5 32	0·099	8·53	0·600	28, 9h 26m	−2·612	147·98	3·255
7 11	−0·193	10·18	0·893	1 11	−2·658		
23, 7h 52m	−0·643	22·87	1·343	4 20	−2·695		
12 35	−0·794	27·58	1·494	29, 8h 59m	−2·875	171·72	3·624
3 25	−0·880	30·42	1·580	12 42	−2·923		
24, 9h 21m	−1·246	43·35	1·946	4 28	−2·974		
12 57	−1·320	51·95	2·020	30, 8h 57m	−3·100	195·80	3·913
4 16	−1·384	55 27	2·084	1 10	−3·217		
26, 8h 57m	−1·993	99 31	2·749	4 17	−3·261		
12 10	−2·050						
3 49	−2·105						

* Adjusted $\tau + b + f$.

TABLE 21.—APPARATUS IV.

$R=314^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 33, glass-hard, $T=-180°$; No. 34, annealed at 1000°, $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 21, 4h 15m	(*)	0·00	(*)	July 29, 9h 02m	−2 324	189·18	3·467
4 43	1·249	0·47	−0·149	12 45	−2·367		
5 23	1·089	1·13	+0·010	4 31	−2·409		
5 45	1·022	1·50	0·077	30, 9h 00m	−2 583	212 61	3·730
6 12	0·957	1·95	0·142	1 13	−2 633		
22, 8h 42m	0·162	16·45	0·037	4 22	−2·673		
12 00	0·042	19·75	1·057	31, 9h 52m	−2 850	236 61	3·952
5 33	−0·250	25·30	1·249	12 41	−2 882		
7 12	−0·185	26·95	1·284	4 01	−2·912		
23, 7h 53m	−0·448	39·63	1·547	Aug. 2, 10h 02m	−3·264	284·95	4·389
12 36	−0·559	44·35	1·658	1 24	−3·291		
3 36	−0·628	47·35	1·727	4 10	−3·312		
24, 9h 23m	−0·924	68·64	2·082	3, 9h 47m	−3·423	308·93	4·534
12 59	−0·985			1 22	−3·436		
4 19	−1·038			4 24	−3·442		
26, 9h 05m	−1·540	116·14	2·685	4, 1h 38m	−3·548	334·78	4·654
12 14	−1·581			4 26	−3 560		
3 52	−1·633			5, 1h 40m	−3 660	359·31	4·768
27, 9h 03m	−1·807	140·35	2·951	5 27	−3·675		
12 34	−1·851			6, 9h 14m	−3 733	381.10	4·855
4 10	−1·895			5 28	−3·777		
28, 9h 29m	−2·081	164·79	3·222	7, 9h 22m	−3·829	405·80	4·946
1 16	−2·125			6 43	−3·863		
4 23	−2·159						

* Adjusted, $r+b+f$.

The results of these tables are given in Fig. 12 on the plan already indicated. The observed differences are probably more largely due to the glass-hard wires than to the soft wires of the twisted system. To compare soft wires these must be specially countertwisted so as to secure greater accuracy of measurement.

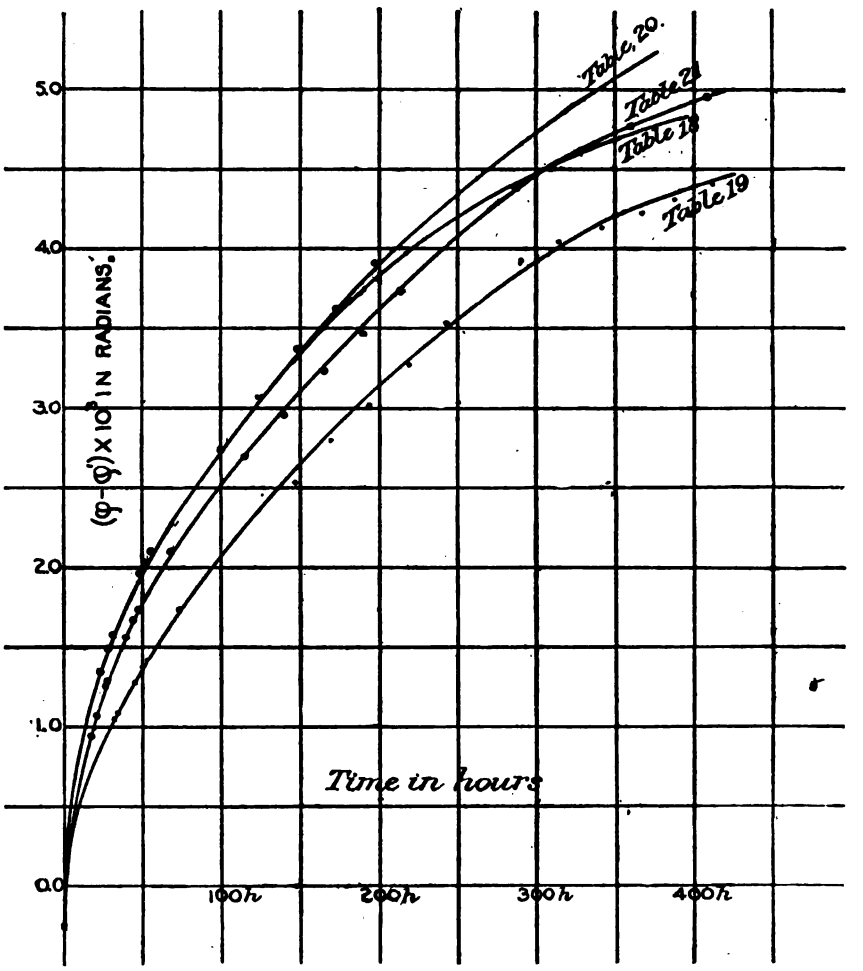

FIG. 12.—Viscous deformation of steel annealed at 1,000° ("soft") compared with glass-hard steel.

REMARKS ON THE TABLES.

23. In experimenting with couples of two glass-hard wires, or with couples in which one of the wires is annealed at 100°, the degree of hardness of the harder wire is an exceedingly important factor. Hence these curves (Tables 3, 4, 5, 6, 7, 8) appear under a variety of forms. Only Tables 4, 6, 7, 8 are used in the digest constructed below. The *results in Tables* 15, 19, 21 change their curvature after August 1.

Since the same error is found in all the wires then examined it is probably a result of temperature. When minutely traced (cf. Table 18, for instance), the curves show a sinuous outline which is quite marked and probably also due to temperature or to tremors. If the curves for stated temperatures and times of annealing fail to coincide, it is due to differences in the tempers of the glass-hard wires, to similar differences in the tempers of the annealed wires, to preexisting strains accidentally imparted to one wire or the other, to lack of perfect uniformity of temper throughout the efficient lengths, to unavoidable inequalities of the sectional areas of the pairs of wires. The last-named error probably also affects the curvature. Viscous rotation of the arms which carry the mirrors, or yielding of the cement, is nil and is not to be apprehended, since the fixed mirror is a fiducial mark for the movable mirror. In the above work we do not indicate the amount of permanent torsion left in each wire after the experiment is finished. Though an important desideratum, it does not fall within the scope of this chapter but will be given in Chapter III in connection with other work there discussed. The effect of temperature on twisted systems of pairs of identical steel wires we investigate in Chapter II, and then discuss the amount of detorsion due to annealing at stated temperatures and times. The soft ends introduce no serious error because soft steel is more viscous than hard steel. The amount of twist registered is that between the upper and lower points of attachment. The included wires must be of uniform hardness.

The fact that an effect of the bifilar and flexural components is wholly absent in these results is proved by Table 11, in which the curve for $\tau+b+f$ is followed without break of continuity by the curve $\tau-b-f$, and the total curve is practically identical with the locus for Table 10. It is proved, moreover, by Tables 1, 2, in which couples of glass-hard wires show no greater difference than is at once attributable to unavoidable differences of hardness; and by Table 30 below, in which $\tau+b+f$ and $\tau-b-f$ produce practically identical zero effects on two soft wires. It is generally proved by the distribution of the 50 rods examined in a diagram of viscosity conformably with the respective tempers of the rods. If a couple of one hard and one soft rod possessed a smaller total of viscosity than a couple of two hard rods, then the bifilar and flexural couples might produce an effect in the former case and not in the latter. The absence of all effect in the case of two soft rods as well as in the case of two hard rods shows that the discrepancy in question is nil. The important bearing of this result will be indicated below.

MISCELLANEOUS EXPERIMENTS.

24. *Glass fibers.*—In Tables 22, 23 we cite the results obtained when one of the steel rods is replaced by a fiber of glass. The mean thickness or the diameter $2\rho_2$ of glass was intended to be that of the steel rod $2\rho_1$; but it is smaller in Table 22 and considerably larger in Table 23. It is

impossible to store a greater total torsion than $T_1-(-T_2)=90°$ in the given system, without breaking the glass fiber. The equality of T_1 and T_2 is assumed merely for convenience in designation (cf. pp. 12, 40). In Table 23, moreover, the glass-hard rod used during the first half of the experiment is replaced by an annealed rod in the second half, leaving the glass fiber unaltered. The suspension here is practically unifilar, since it is nearly impossible mechanically to clutch the glass fiber without breaking it.

TABLE 22.—APPARATUS I.

$R=215^{cm}$; $l=27^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 35, glass-hard steel, $T_1=+45°$; No. *a*, glass fiber, $T_2=-45°$; $\rho_s=0{\cdot}082^{cm}$; $\rho_g=0{\cdot}070^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
June 29, 3h 20m	(*)	0·00	(*)	July 3, 8h 17m	0·974	88·95	1·075
3 42	−0·129	0.37	−0·028	12 12	0·991	92·87	1·092
4 20	−0·101	1·00	±0·000	6 27	1·026	99·12	1·127
5 30	−0·052	2·17	+0·049	4, 9h 45m	1·098	114·42	1·199
5 51	−0·031	2·52	0·070	12 09	1·109	116·82	1·210
30, 8h 50m	+0·351	17·50	0·452	3 06	1·116	119·77	1·217
12 23	0.413	21·05	0·514	5 59	1·145	122·65	1·246
1 57	0.440	22·62	0·541	5, 9h 39m	1·213	138·32	1·314
5 22	0·486	26·03	0·587	12 00	1·228	140·67	1·329
July 1, 8h 37m	0 653	41·28	0·753	4 43	1·257	145·38	1·358
2 12	0·706	46·87	0·807	6, 8h 40m	1·318	161·33	1·419
4 36	0·732	49·27	0·833	1 52	1·339	166·53	1·440
5 37	0·741	50·28	0·842	5 15	1·355	169·92	1·456
6 57	0·753	51·62	0·854	7, 8h 49m	1·420	185·48	1·521
2, 9h 19m	0·854	65·98	0·955	1 27	1·443	190·12	1·444
1 45	0·879	70·42	0·980				
5 09	0·899	73·82	1·000				

* Adjusted.

TABLE 23.—APPARATUS I.

$R=223^{cm}$; $l=23^{cm}$. Rods: No. 36, glass-hard steel, $T_1=+45°$; No. *b*, glass fiber, $T_2=-45°$; $2\rho_s=0{\cdot}082^{cm}$; $0{\cdot}085^{cm}<2\rho_g<0{\cdot}120^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 7, 4h 15m	(*)	0·00	(*)	July 12, 7h 35m	3·100	111·33	−0·235
4 26	2·995	0·18	−0·130	Glass-hard rod replaced by soft steel rod, viz: No. 42, annealed, 450°, 1h, $T_1=+45°$, $2\rho=0{\cdot}082^{cm}$.			
4 38	2·934	0·38	−0·069				
5 15	2·865	1·00	±0·000	July 12, 9h 39m	(*)	0·00	(*)
8, 9h 14m	2·823	16·98	+0·042	9 49	1·358	0·17	−0·023
12 41	2 841	20·43	0·024	10 54	1 331	1·25	+0·004
4 07	2·858	23·87	0·007	5 25	1·303	7·77	0·032
5 47	2·863	25·53	0·002	13, 8h 26m	1·278	22·78	0·057
9, 8h 33m	2·912	40·30	−0·047	12 27	1·270	26·80	0·065
12 10	2·928	43·92	−0·063	5 06	1·270	31·45	0·065
5 16	2·940	49·02	−0·075	14, 8h 50m	1·258	47·18	0·077
10, 8h 04m	2·983	63·82	−0·118	12 48	1·258	51·15	0·077
12 08	2·996	67·88	−0·131	4 40	1·255	55·02	0·080
5 18	3·010	73·05	−0·145	15, 10h 45m	1·245	73·10	0·090
11, 9h 07m	3·053	88·87	−0·188	4 25	1·245	78·77	0 090
11 23	3·058	91·13	−0·193	16, 9h 16m	1·237	95·62	0·098
5 21	3·077	97·10	−0·212	1 42	1·237	100·05	0 098
6 59	3·081	98·73	−0·216	5 54	1·236	104·25	0·099

* Adjusted.

The results obtained with glass are given in Fig. 13. The thinner glass fiber is uniformly less viscous than steel. The thicker fiber lies between hard steel and soft steel in viscosity. But the occurrence of the maximum is noteworthy. Glass is here initially more and ultimately less viscous than hard steel.

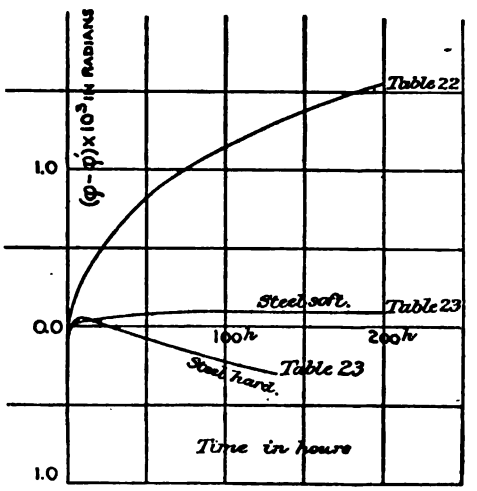

FIG. 13.—Viscous deformation of steel as compared with glass.

25. *Iron, soft and drawn.*—Tables 24, 25, 26, 27, contain a part of our results in which one steel wire is replaced by a wire of wrought iron, annealed or drawn as specified. That the amounts of torsion are equal in angle (T) is again assumed for convenience of designation only. ρ_s is the radius of steel, ρ_i of the iron wire. The applied couple twists soft iron beyond the limits of elasticity and the amount of instantaneous detorsion is here probably as large as $\frac{1}{2}(T_1+T_2)$. In case of steel instantaneous detorsion is nearly zero.

TABLE 24.—APPARATUS I.

$R=223^{cm}$; $l=26^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 37, steel, annealed at 450°, 1^h, $T=+180°$; No. 6, wrought iron, drawn, $T=-180°$. $2\rho_s=0{\cdot}082^{cm}$; $2\rho_i=0{\cdot}083^{cm}$.

Date.	$N\times10^3$	λ_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	λ_0	$(\phi-\phi')\times10^3$
July 17, 4^h 20^m	1·955	0·20	—0·387	July 18, 8 $^h27^m$	2·177	16·32	—0·165
4 23	2·032	0·25	—0·310	2 24	2·122	22·27	—0·220
4 27	2·118	0·32	—0·229	19, 9^h 37^m	2·032	41·48	—0·310
4 51	2·285	0·72	—0·057	12 19	2·025	44·18	—0·317
5 20	2·342	1·20	±0·000	5 10	2·014	49·03	—0·328
6 01	2·362	1·88	+0·020	20, 8^h 29^m	1·984	64·35	—0·358
				8 45	1·977	71·62	—0·364

* Adjusted $\tau-b-f$.

TABLE 25.—APPARATUS I.

R = 217^{cm}; l = 27^{cm}; λ<0·2^{cm}. Rods: No. 49, glass-hard, T = −180°; 2ρ = 0·062^{cm}; No. *h*, wrought iron, drawn, T = +180°; 2ρ = 0·080^{cm}.

Date.	*h*	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Remarks.
Aug. 31, 5^h 45^m	0·00	.....	0·00	.....	Adjusted, $\tau+b+f$.
5 55	0·17	0·967	0·17	−0·267	
6 30	0·75	0·785	0·75	−0·085	
Sept. 1, 8^h 58^m	15·22	+0·017	15·22	+0·683	
1 00	19·25	−0·072	19·25	0·772	
6 12	24·45	−0·166	24·45	0·866	
2, 9^h 05^m	39·33	−0·376	39·33	1·076	
5 34	47·82	−0·470	47·82	1·170	
3, 10^h 02^m	64·28	−0·626	69·23	.....	
7 55	74·17	−0·713	.....	1·370	
4, 9^h 02^m	87·28	−0 805	92·60	.....	
7 40	97·92	−0 878	.....	1·542	
5, 9^h 50^m	112·08	−0·970	116·42	.....	
6 30	120·75	−1·032	.....	1·701	
6, 9^h 05^m	135·33	−1·124	135·33	1·824	Untwisted.

TABLE 26.—APPARATUS II.

R = 200^{cm}; l = 27^{cm}; λ<0·2^{cm}. Rods: No. 38, steel, annealed at 450°, 1^h, T = +180°; No. *d*, wrought iron, soft, T = −180°. $2\rho_s$ = 0·082^{cm}; $2\rho_t$ = 0·112^{cm}.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 16, 9^h 40^m	(*)	0·00	(*)
9 48	0·714	0·13	−0·026
11 14	0·745	1·57	+0·005
1 48	0·758	4·13	0·018
5 47	0·750	8·23	0·010
17, 8^h 47^m	0 731	23·12	−0·009
Thick iron wire replaced by thin wire. Rod No. 9, wrought iron, soft; T = −180°; 2ρ = 0·083^{cm}.			
17, 5^h 26^m	0·755	‡ 0·00	−0·019
5 30	0·745	0·07	−0·009
5 36	0 736	0·17	±0·000
6 00	0·718	0·57	+0·018

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 18, 8^h 33^m†	0.146	15·12	(0·153)
2 35	0·151	21·15	(0·148)
19, 9^h 38^m	0·128	(40·20)	(0·171)
12 20	0·119	(42·90)	(0·180)
5 10	0·110	(47·73)	(0·189)
20, 8^h 28^m	0·082	(63 03)	(0·217)
3 44	0·064	(70·32)	(0·235)

* Accident; new adjustment; data otherwise good, but distinguished by parentheses.

† Adjusted $\tau-l-f$.

‡ Adjusted $\tau+l+f$, but the time not accurately noted.

TABLE 27.—APPARATUS II.

R = 202^{cm}; l = 26^{cm}; λ<0.2^{cm}. Rods: No. 50, annealed at 350°, 1^h, T = +180°; No. *k*, wrought iron, drawn, T = −180°. $2\rho_t$ = 0·084^{cm}; $2\rho_s$ = 0·082^{cm}.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 23, 2^h 00^m	(*)	0·00	(*)
2 13	2·052	0·22	−0·452
2 20	1·914	0·33	−0·314
3 11	1·599	1·18	+0·001
5 37	1·417	3·62	0·183
7 11	1·392	5·18	0·208
24, 9^h 17^m	1·385	19·28	0·215
5 13	1·411	27·22	0·189
25, 9^h 05^m	1·435	43·08	0·165
7 00	1·448	53·02	0·152
26, 9^h 10^m	1·460	70·65	0·135
4 08	1·469		

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 27, 9^h 10^m	1·483	96·38	0·114
7 36	1·490		
28, 9^h 21^m	1·492	120·13	0·107
6 55	1·494		
29, 10^h 11^m	1·500	144·23	0·100
6 17	1·501		
30, 9^h 11^m	1·505	168·18	0·095
31, 1^h 19^m	1·515	193·66	0·085
6 00	1·515		
Sept. 1, 9^h 19^m	1·517	211·32	0·083
2, 9^h 05^m	1·524	237·29	0·074
1 30	1·528		

* Adjusted $\tau+l+f$.

Figure 14 contains the results of Tables 24, 25, 26 and 27. The signs of ordinate and twist agree for the wire of greater viscosity. The phenomena are here of a complicated kind, showing that viscous motion in iron and steel is not similar. The sharp maximum of Table 24 is specially noteworthy; as is also the less pronounced maximum of Table 27—both of which hold for drawn iron. A maximum is also apparent in the thick, soft wire of Table 26; whereas the thin, soft wire of this table and the soft wire iron of Table 25 show no retrogression.

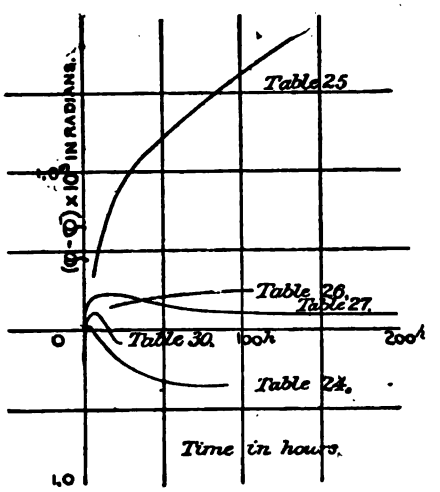

FIG. 14.—Viscous deformation of steel compared with iron, soft and drawn.

Other allied data are as follows:

TABLE 28.—APPARATUS I.

$R=202^{mm}$; $l=27^{mm}$; Rods: No. 55, steel, annealed at 450°, $2\rho=0{\cdot}062^{mm}$; T positive; No. m wrought iron, soft, $2\rho=0{\cdot}080^{mm}$; T negative.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Sept. 6, 9h 30m	0·00	.....	0·00	.....	Sept. 9, 10h 05m	72·58	0·535	70·79	0·307
9 42	0·20	0·200	0·20	−0·050	6 30	81·00	0·590		
8 52	0·37	0·223	0·37	−0·027	10, 3h 32m	102·03	0·664	104·26	0·421
1 57	4·45	0·307	4·45	+0·057	8 00	106·50	0·678		
7 12	9·70	0·333	9·70	+0·083	11, 9h 03m	119·55	0·721	124·99	0·478
7, 9h 11h	23·68	0·375	23·68	0·125	7 55	130·42	0·735		
6 11	32·68	0·397	32·68	0·147	12, 9h 43m	144·22	0·751	147·95	0·508
8, 10h 42h	49·20	0·444	53·70	0·211	5 10	151·67	0·761		
7 42	58·20	0·478							

TABLE 29.—APPARATUS II.

$R=200^{cm}$; $l=27^{cm}$. Rods: No. 56, steel, annealed at 450°; $2\rho=0{\cdot}052^{cm}$; No. n, iron, soft; $2\rho=0{\cdot}083^{cm}$; $T_2=+90°$; $T_1=-90°$.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Sept. 6, 10h 00m	0·00	.....	0·00	.....	13, 10h 20m	168·32	3·067	173·75	1·012
10 12	0·20	2·072	0·20	—0·008	9 10	179·17	3·116		
1 57	3·95	2·118	3·95	+0·038	14, 9h 00m	191·00	3·153	196·12	1·089
7 12	9·20	2·128	9·20	+0·048	7 14	201·23	3·184		
7, 9h 11m	23·22	2·163	23·22	0·083	15, 9h 00m	215·00	3·225	220·20	1·155
6 11	32·22	2·205	32·22	0.125	7 24	225·40	3·244		
8, 10h 42m	48·70	2·307	53·20	0·259	16, 9h 34m	239·57	3·280	244·35	1·213
7 42	57·70	2·371			7 07	249·12	3·307		
9, 10h 05m	72·08	2·477	76·20	0·428	17, 9h 20m	263·33	3·347	268·16	1·283
6 30	80·50	2·539			7 00	273·00	3·379		
10, 3h 32m	101·53	2·685	103·77	0·620	18, 9h 10m	287·17	3·415	293·15	1·353
8 00	106·00	2·715			9 08	299·13	3·451		
11, 9h 03m	119·05	2·807	124·48	0.760	19, 11h 55m	313·92	3·491	313·92	1·411
7 55	129·92	2·885			20, 9 06	335·10	3·541	335·10	1·461
12, 9h 43m	143·72	2·938	147·45	0·879	21, 9 22	350·37	3·559	350·37	1·479
5 10	151·17	2·980			28, 2 33	532·55	3·767	532·55	1·687

Permanent set 180° in iron.

TABLE 30.—APPARATUS III.

$R=370^{cm}$; $l=20^{cm}$; $\lambda<0{\cdot}2^{cm}$. Rods: No. 51, soft, $T=-180°$; No. 52, annealed at 450°; $T=+180°$. $2\rho=0{\cdot}082^{cm}$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Aug. 20, 12h 35m	(*)	0·00	(*)	Aug. 25, 9h 05m	0·581	92·80	0·027
12 50	0·291	0·25	—0·004	7 01	0·568		
6 44	0·306	6·15	+0·011	26, 9h 10m	0·568	115·40	0·014
21, 9h 07m	0·314	20·53	0·019	4 08	0·556		
5 00	0·311	28·42	0·016	27, 9h 10m	0·548	144·13	—0·009
21, 5h 15m	(†)	0·00	(†)	7 36	0·530		
5 25	0·546	0·16	—0·002	28, 9 20m	0·530	164·87	—0·023
7 08	0·551	1·88	+0·003	6 55	0·520		
22, 9h 57m	0·556	16·70	0·008	29, 10h 1m2	0.515	188·99	—0·037
6 54	0·561	25·65	0·013	6 17	0·507		
23, 9h 08m	0·561	39·88	0·013	30, 9h 11m	0·505	207·93	—0·043
5 37	0·561	48·36	0·013				
24, 5h 18m	0·581	68·00	0·033				
5 13	0·581						

* Adjusted $\tau-b-f$. † Readjusted $\tau+b+f$.

Table 30 shows very clearly, the relatively insignificant difference which exists between steel annealed at 450° and soft steel, so far as viscosity is concerned. This difference is less than that between steel

and iron, as well as different in character. The results of Tables 28, 29, 30 containing further indication of the behavior of soft metal are given in Fig. 15.

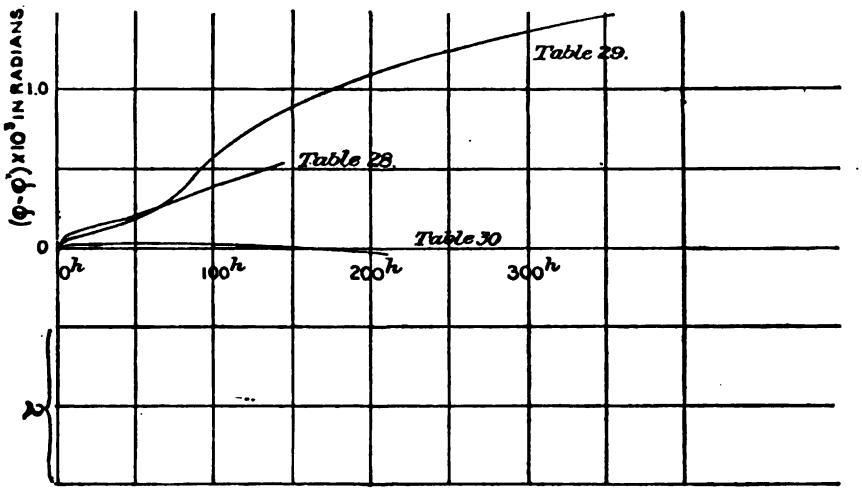

FIG. 15.—Viscous deformation of steel compared with iron.

For the purpose of further fixing the ideas I add some data with other metals. The results are to be constructed graphically in Figs. 16, 17. These relative results are difficult to interpret because of the varying amounts of permanent set incident to the experiments. To meet these errors the method must be varied as indicated in Chapters II and III.

Nickel and copper.—The data in hand are as follows:

TABLE 31.—APPARATUS III.

R=370^{cm}; l=27^{cm}. Rods: No. 61, steel, annealed soft; 2ρ=0·044^{cm}; No. p nickel, annealed soft, 2ρ=0·048^{cm}; T_s = +180°; T_n = −180°.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Remarks.
Sept. 15, 11^h 30^m	0·00	.....	0·00	.....	Adjusted
11 45	0·25	0·346	0·25	−0·004	
7 22	7·87	0·371	7·87	+0·021	
16, 9^h 34^m	22·07	0·386	22·07	0·036	
7 15	31·75	0·396	31·75	0·046	
17, 9^h 20^m	45·83	0·306	50·72	0·049	
7 07	55·62	0·401			
18, 9^h 09^m	69·65	0·396	75·65	0·023	
9 09	81·65	0·351			
19, 11^h 55^m	96·42	0·346	96·42	−0·004	
20, 9 05	117·68	0·352	117·68	+0·002	
26, 11 30	312·00	0·371	312·00	+0·021	

TABLE 32.—APPARATUS IV.

$R=314^{cm}$; $l=27^{cm}$. Rods: No. 62, steel annealed at 450°; $2\rho=0{\cdot}082^{cm}$; No. q copper drawn; $2\rho=0{\cdot}083^{cm}$; $T_s=+90°$; $T_c=-90°$.

Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$
Sept. 10, 3h 06m	0·00	.....	0·00	.....	Sept. 15, 9h 00m	113·90	1·032	119·11	0·388
3 30	0·40	0·670	0·40	—0.030	7 25	124·32	1·094		
8 00	4·90	0·850	4·90	+0·150	16, 9h 35m	138·48	1·106	143·27	0·409
11, 9h 00m	17·90	0·940	17·90	0·240	7 16	148·07	1·112		
7 55	28·82	0·963	28·82	0·263	17, 9h 19m	162·22	1·118	167·12	0·418
12, 9h 45m	42·65	0·995	47·12	0·305	7 07	172·02	1·118		
6 41	51·58	1·016			18, 9h 10m	186·07	1·118	19·207	0·412
13, 10h 19m	67·22	1·022	72·66	0·328	9 10	198 07	1·106		
9 12	78·10	1·034			19, 11h 55m	236·82	1·112	236·82	0·412
14, 9h 00m	89·90	1·046	95·03	0·352	20, 9 05	245·98	1·117	245·98	0·417
7 15	100·15	1·058							

Permanent set in copper 180°.

TABLE 33.—APPARATUS I.

$R=202^{cm}$; $l=27^{cm}$. Rods: No. 63, steel, soft drawn, $2\rho=0{\cdot}082^{cm}$; No. r copper, softened; $2\rho=0{\cdot}080^{c}$; T_s positive. T_c negative.

Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$
Sept. 3, 1h 55m	0·00	.....	0·00	.....	Sept. 14, 9h 00m	19·08	0·427	19·08	0·033
2 06	0·18	0·468	0·18	—0·008	1 23	23·47	0·426	23·47	0·034
9 10	7·25	0·447	7·25	+0·013					

Permanent set in copper nearly 360°.

TABLE 34.—APPARATUS I.

$R=202^{cm}$; $l=27^{cm}$. Rods: No. 64, steel, soft; $2\rho=0{\cdot}082^{cm}$; $T=+45°$; No. s copper, softened, $2\rho=0{\cdot}155^{cm}$ $T=-45°$.

Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_e	$(\phi-\phi')\times10^3$
Sept. 14, 1h 40m	0·00	.....	0·00	.....	Sept. 17, 9h 20m	67·67	1·179	72·55	0·186
1 47	0·12	0·920	0·12	—0·080	7 05	77·42	1·193		
1 58	0·30	0·942	0·30	—0·058	18, 9h 10m	91·50	1·208	97·47	0·214
7 13	5·55	1·044	5·55	+0·044	9 06	103·43	1·221		
15, 9h 00m	19·33	1·112	19·33	0·112	19, 11h 55m	117·75	1·235	117·75	0·235
7 22	29·70	1·140	29·70	0·140	20, 9 05	139·42	1·250	139·42	0·250
16, 9h 33m	43·88	1·157	48·65	0·163	21, 9 20	163·67	1·260	163·67	0·260
7 06	53·43	1·167							

Permanent set of copper 270°.

The viscosity of nickel as compared with soft steel (Fig. 17) is worthy of note. The small deformations of copper are the result of the unavoidably small stress intensities which actuate the viscous motion.

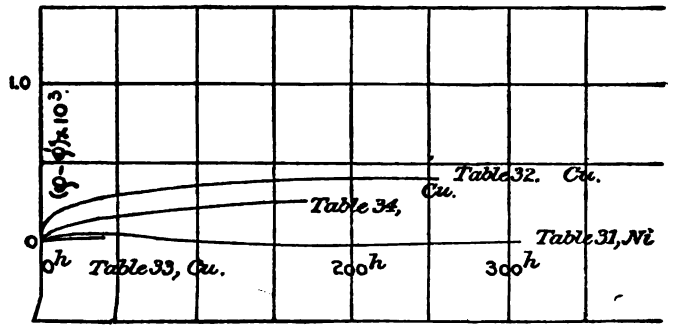

FIG. 16.—*Viscous deformation of copper and nickel compared with steel annealed at 450°.*

27. *Steels annealed at* 450° *and* 1000°.—The data in hand are as follows:

TABLE 35.—APPARATUS III.

$R=370^{cm}$; $l=27^{cm}$. Rods: No. 57, steel annealed at 450°; $T=+180°$; No. 58, steel, commercial, softened; $T=-180°$; $2\rho=0{\cdot}082^{cm}$.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Sept. 4, 9h 20m	0·00	.....	0·00	.....	Sept. 8, 10h 42m	97·37	0·485	101·87	0·190
9 33	0·22	0·294	0·22	−0·006	7 42	106·37	0·495		
7 40	10·33	0·371	10·33	+0·071	9, 10h 02m	120·70	0·505	124·93	0·210
5, 9h 47m	24·45	0·411	24·45	0·111	6 30	129·17	0·515		
6 30	33·17	0·425	33.17	0·125	10, 3h 30m	150·17	0·525	150·17	0·225
6, 9h 05m	47·75	0·450	52·79	0·153					
7 10	57·83	0·455							
7, 9h 10m	71·83	0·465	76·34	0·167					
6 11	80·85	0·470							

TABLE 36.—APPARATUS IV.

$R=314^{cm}$; $l=27^{cm}$. Rods: No. 59, steel annealed at 450°, $2\rho=0{\cdot}082$, T positive; No. 60, steel softened from hardness, $2\rho=0{\cdot}082$, T negative.

Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	h	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
Sept. 4, 9h 40m	0·00	.....	0·00	.....	Sept. 7, 9, 10m	71·50	0·078	76·00	0·022
9 55	0·25	0·105	0·25	−0·002	6 11	80·50	0·084		
7 40	10·00	0·096	10·00	+0·007	8, 10h 42m	97 03	0·090	101·53	0·013
5, 9h 47m	24·12	0·084	24·12	0·019	7 42	106·03	0·089		
6 30	32·83	0·084	32·83	0·019	9, 10h 02m	120·37	0·102	124·60	0·001
6, 9 05m	47·42	0·078	52·46	0·022	6 30	128·83	0·102		
7 10	57·50	0·084							

The results for soft steels are constructed in Fig. 17, and corroborate Table 30 above, with reference to the small differences between steel annealed at 450° and steel annealed at 1000°.

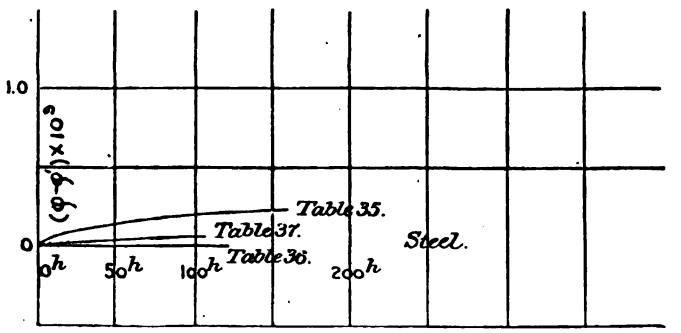

FIG. 17.—Viscous deformation of steel annealed at 450°, compared with soft steel.

28. *Quadrifilar arrangement.*—Table 37 contains results for a quadrifilar as explained below. The small differences of viscosity in question are scarcely sufficient to give character to the motion when the stress given is applied to such thin wires. Further experiments were not made.

TABLE 37.—APPARATUS III.

Quadrifilar suspension; $l=27^{cm}$; $R=370^{cm}$. Rods: No. 58, soft; $T_1=(+180°)+90°$; No. 57, annealed at 450°; $T_2=(-180°)+90°$; No. 60, soft; $T_3=(+0°)-90°$; No. 59, annealed at 450°; $T_4=(-0°)-90°$, $\rho=0{\cdot}082^{cm}$.

Date.	A	$N\times10^3$	A_0	$(\phi-\phi')\times\frac{1}{10^3}$	Date.	A	$N\times10^3$	A_0	$(\phi-\phi')\times\frac{1}{10^3}$
Sept. 10, 3h 45m	0·00	.....	0·00	.....	Sept. 13, 10h 20m	66·58	0·856	72·02	0·055
4 03	0·30	0·906	0·30	0·000	9 12	77·45	0·848		
5 00	4·25	0·906	4·25	0·000	14, 9h 00m	89 25	0·846	94·36	0·060
11, 9h 00m	17·25	0 898	17·25	0·008	7 14	99·48	0·846		
7 55	28·17	0·871	28·17	0·035	15, 9h 00m	113·25	0·866	113·25	0·040
12, 9h 45m	42·00	0·866	46·46	0·038					
6 41	50·93	0·871							

29. *Tubular apparatus.*—Table 38 and 39 contain our results with the tubular apparatus. ρ_1 is the inner radius, ρ_2 the outer radius of the tube. Q and q denote the right sections of brass tube and steel wire respectively. Of course sections of metallic surface are meant. The inclosed wire is twisted alternately in opposite directions as is indicated by the sign of T. The result is similarly indicated by the sign of $(\varphi-\varphi')$. Subscripts s and b refer to steel and brass respectively. Table 38 contains results for a thick tube, Table 39 for a thin tube. Hard or soft rods are inserted, as indicated.

TABLE 38.—APPARATUS (tubular) II.

$R=260^{cm}$, $l=22^{cm}$. Rods: No. s, brass, $2\rho_1=0{\cdot}188^{cm}$, $2\rho_2=0{\cdot}320^{cm}$. No. 89, steel, glasshard, $2\rho=0{\cdot}127^{cm}$; $Q=0{\cdot}053^{cm^2}$; $q=0{\cdot}0127^{cm^2}$; $Q/q<4{\cdot}5$.

Date.	$N\times10^3$	A_0	$(\phi-\phi')\times10^3$	Date.	$N+10^3$	A_0	$(\phi-\phi')\times10^3$
July 7, 9h 02m	0·308	*0·00	+0·002	July 14, 8h 57m	0·248	*0·00	±0·000
12 15	0·390	3·22	—0·080	10 27	0·248	1·50	±0·000
5 18	0·420	8·27	—0·110	12 45	0·248	3·80	±0·000
8, 9h 19m	0·460	24·28	—0·150	4 45	0·250	7·80	+0·002
12 48	0·465	27·77	—0·155	15, 10h 46m	0·250	25·82	+0·002
5 50	0·476	32·80	—0·166	15, 10h 46m	.....	*0·00	.....
9, 8h 30m	0·500	47·47	—0·190	12 35	0·310	1·82	—0·005
9, 8h 50m	0·456	†0·00	—0·050	4 27	0·306	5·08	—0·009
12 12	0·337	3·37	+0 063	16, 9h 20m	0·299	22·57	—0·016
5 20	0·283	8 50	+0·117	Original hard steel rod, No. 39, again inserted.			
10, 8h 09m	0·222	23·32	+0·178				
12 09	0·208	27·32	+0·192	16, 9h 25m	0·948	*0·00	+0·032
5 18	0·191	32·97	+0·209	11 26	1·009	2·02	—0 029
11, 9h 20m	0·160	48·50	+0·240	1 45	1·028	4·33	—0·048
11 35	0·151	50·75	+0·249	5 58	1·052	8·53	—0·072
4 15	0·142	55·42	+0·258	17, 8h 50m	1·093	23·42	—0·113
11, 4h 15m	0·540	*0·00	+0·060	12 55	1·102	27·50	—0·122
4 45	0·575	0·20	+0·025	6 04	1·125	32·65	—0·145
5 23	0·597	1·13	+0 003	18, 8h 27m	1·151	47·03	—0·171
7 00	0·630	2·75	—0·030	2 28	1·160	53·05	—0·180
12, 7h 32m	0·718	15·40	—0·118	19, 9h 41m	1·185	72·27	—0·205
5 29	0·743	25·23	—0·143	12 20	1·186	74·92	—0·206
13, 8h 30m	0·779	40·25	—0·179	5 15	1·186	79·83	—0·206
Glass-hard rod replaced by a soft steel rod, viz: No. 40, annealed, 450°, 1h, $2\rho=0{\cdot}127^{cm}$.				20, 8h 28m	1·207	95·06	—0·227
				20, 10h 50m	0·458	†0·00	—0·062
13, 10h 04m	0·876	*0·00	+0·004	11 18	0·416	0 47	—0·020
12 30	0·886	2·43	—0·004	11 50	0·396	1·00	±0·000
5 05	0·890	7·02	—0·010	1 53	0·354	3·05	+0·042
14, 8h 55m	0·894	22·85	—0·014	3 44	0·330	4·90	+0·066
				6 35	0·303	7·75	+0·093
				21, 10h 02m	0·247	23·20	+0·149
				12 18	0·239	25·47	+0·157

* Total twist $T_s-(-T_b)=180°$, twist of steel T_s, positive.

† Total twist $-T_s+(-T_b)=180°$, twist of steel, positive.

TABLE 39.—APPARATUS (tubular) V.

$R=260^{cm}$; $l=22^{cm}$. Rods: No. *f*, brass tube, $\begin{cases}2\rho_1=0{\cdot}19^{cm}.\\2\rho_2=0{\cdot}24^{cm}.\end{cases}$ No. 41, steel, annealed at 450°, 1^h, $2\rho=0{\cdot}082^{cm}$. $Q=0{\cdot}0155^{cm^2}$; $q=0{\cdot}0054^{cm^2}$; $Q/q>2{\cdot}5$.

Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$	Date.	$N\times10^3$	h_0	$(\phi-\phi')\times10^3$
July 22, 2^h 39^m	.....	†0·00	.....	July 28, 9^h 32^m	1·476	120·14	0·392
3 48	3·602	0·17	+0·032	1 18	1·498		
5 39	3·541	2·02	−0·029	4 26	1·502		
7 13	3·518	3·58	−0·053	29, 9^h 04^m	1·511	143·86	0·417
23, 7^h 54^m	3·465	‡16·27	−0·105	12 48	1·518		
12 02	3·435	20·40	−0·135	4 33	1·521		
23, 12^h 57^m	1·026	*0·00	−0·074	30, 9^h 01^m	1·651	*167·90	0·533
3 37	1·147	2·67	+0·047	1 15	1·654		
24, 9^h 28^m	1·289	20·52	0·189	4 16	1·660		
1 03	1·300	24·10	0·200	31, 9^h 54^m	1·671	191·94	0·572
4 23	1·307	27·43	0·207	12 44	1·672		
26, 9^h 08^m	1·398	68·18	0·298	4 03	1·672		
12 17	1·409	71.33	0·309	Aug. 2, 9^h 04^m	1·689	239·95	0·592
3 58	1·417	75·02	0·317	1 27	1·692		
27, 9^h 06^m	1·433	95·71	0·337	4 11	1·695		
12 38	1·437			5, 1^h 42^m	1·727	338·63	0·627
4 13	1·441			5 27	1·727		

* Adjusted anew. † Total twist $T_2-(Tb)=180°$, twist of steel positive.
‡ Total twist $-T_2+(+Tb)=180°$, twist of steel negative.

The results of Tables 38, 39 are given graphically in Fig. 18, on a scale ten times as large as in the earlier figures. The figure shows the gradual reduction of viscous motion in the consecutive alternate twists.

We have not yet made the tubular apparatus as sensitive in its indications as is the bifilar. To obtain the full benefit of this adjustment long tubes and wires should be used. The results are nevertheless sufficiently sharp and pronounced and are cited here for their important bearing in the inferences to be drawn for steel. Fine glass tube is to be preferred to brass.

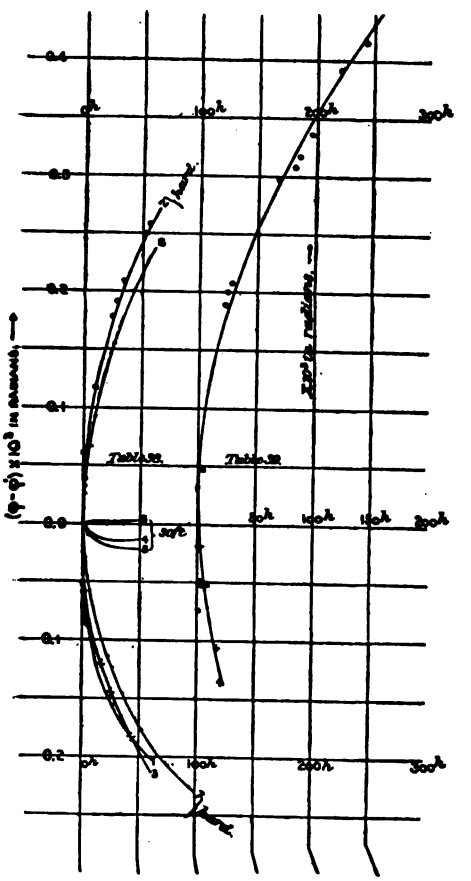

FIG. 18.—Results obtained with the tubular apparatus.

DISCUSSION.

30. *Interpretation of* $(\varphi-\varphi')$. Before proceeding further it is necessary to give the quantity $(\varphi-\varphi')$ a more specific interpretation than appears from a persual of the above paragraphs. Since the wires *are 30^{cm} long*

and but .08cm in diameter, the considerations are much simplified by conceiving the twist helix of each wire to be developed, or rolled out on a plane surface. Fig. 19 indicates the result in a diagrammatic way. Here *ab* and *bd* are the developed position of two corresponding fibers (helices) of the countertwisted wires *A* and *A'*, *df* and *ag* being the lengths, *l* and *bf* and *bg* the cylindrical semicircumferences of the two wires, respectively. For in the usual cases above $bf = T = bg = 180°$. Hence *df* is usually more than 100 times as long as *bf*, and the same ratio holds for *ag* and *gb*. Hence also the angle *dbf* expresses the rate of twist; and for want of data indicating the precise relation between the rigidities of steel of different tempers, the angles *dbf* and *abg* must throughout the present volume be regarded equal.

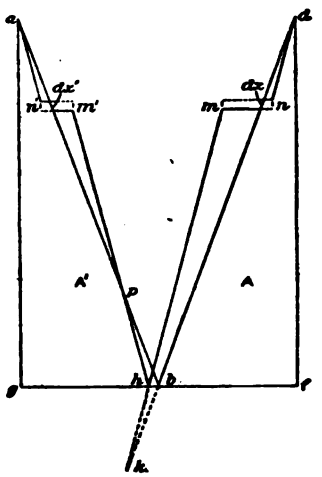

FIG. 19.—Diagram.

Suppose now that at any section of the wires, and at a distance x and x' respectively above the lower end, viscous sliding takes place, on both the plane surfaces of an elementary cylinder, of the length dx and dx' respectively. Now it is clear from the equality of couples, that the sliding on the two plane faces of the cylinder dx will be equal, and opposite in direction. The same is true of the sliding on the two ends of dx'. It is also clear that throughout this sliding the elastic equilibrium of the system of two wires is continually being disturbed. Therefore the viscous motion must be accompanied by purely elastic motion of the whole system, such that throughout every stage of viscous deformation the rate of twist is kept constant. From these conditions it follows that after a very short time dt, the originally straight fibers *db* and *ba* will make up a broken line *dnmh* and *hm'n'a*; that furthermore *dn* and *hm* must be parallel, *hm'* and *n'a* be also parallel, and that the angles *mhf* and *m'hg* are equal. Clearly *hb* corresponds to the motion observed at the movable mirror of the bifilar suspension (Fig. 1), and may therefore easily be interpreted.

Prolong the lines *db* and *mh* till they meet at *k*. The triangles *pbh* and *hbk* are equal in all their parts. Hence $pb = bk = y$.

Let 2φ be the amount of viscous angular motion of any section of the wire *A*, relative to another section at a unit distance from it, under the given conditions of adjustment. Let $2\varphi'$ have the same signification for *A'*. Then since the same couple acts throughout the length of either wire, $mn = 2\varphi dx$ and $m'n' = 2\varphi' dx'$, no matter what be the value of x or x'.

Let $d\psi$ be the angular motion at the mirror, so that $d\psi=hb$. Then for an inspection of the figure it follows that

$$\frac{2\varphi dx}{d\psi}=\frac{l}{y}+1 \qquad \text{and} \qquad \frac{2\varphi' dx'}{d\psi}=\frac{l'}{y'}-1.$$

whence by elimination, since

$$l=l',\ y=y',\ dx=dx',\ d\psi=(\varphi-\varphi')dx', \quad \ldots\ (1)$$

and by integration

$$\varphi-\varphi'=\psi/l \quad \ldots\ (2)$$

31. The quantity $\varphi-\varphi'$ defined by equation (2) is clearly identical with the $(\varphi-\varphi')$ of the above tables. The signification of the symbol is therefore evident. In case of any stated twist stored between the two bifilar wires, the two end sections of the unit of length of one wire slide viscously 2φ radians relative to each other, whereas the end sections of the other wire slide $2\varphi'$ radians relative to each other.

VISCOSITY AND TEMPER.

32. *Graphic digest.*—The results of Tables 1 to 21 may be discussed in two ways: We may either accept some definite and applicable law like that of Weber or that of Kohlrausch, and calculate the mean constants for each set of results, or we may construct them graphically and then calculate the coordinates of the mean curve for each set. The latter is decidedly the better way, because it is less arbitrary and more convenient. In Table 40 the mean results in question are thus summarized. The first two columns indicate the tables from which in each case the selections are made, and the tempers of the rods selected. The remaining columns contain the differences of viscous detorsion, $(\varphi-\varphi')$, in radians per centimeter of length of the bifilar, one of the wires of which is invariably glass-hard, the other annealed as stated. $(\varphi-\varphi')$ is arbitrarily fixed at zero, for one hour after a twist of $T+180^\circ$ and $T-180^\circ$ has been imparted to the soft and hard wire, respectively.

Instead of making all references to glass-hard wires, it would have been more in keeping with the purposes of the work to make such references to soft wire; but at the outset of the work, the high viscosity of annealed steel, as compared with hard steel, was not known, nor even conjectured.

In the tables and figures the data are positive in the direction of increasing viscosity.

TABLE 40.—*A digest of mean results, Tables* 1 *to* 26.

Table No.	Annealed at	Angular motion ($\phi-\phi'$) in radians.							
		50h	100h	150h	200h	250h	300h	350h	400h
1....	20°	0·13	0·19	0·26	0·34	.....	.....	.....	.....
2.....	20°	0·02	0·03	0·03	0·04	.....	.....	.....	.....
Mean .	.....	0·08	0·11	0·15	0·19	.....	.....	.....	.....
6.....	100°, 10h	0·50	0·81	1·06	1·26	1.42	.....	.....	.....
8.....	...do	0·44	0·75	1·08	1·41	1·24	.....	.....	.....
7.....	...do	0·62	1·00	1·85	1·70	1·99	.....	.....	.....
4.....	...do	0·81	1·28	1·66	1·95	2·18	.....	.....	.....
Mean .	...do	0·59	0·96	1·41	1·58	1·71	.....	.....	.....
9.....	190°, 1h	1·07	1·52	1·88	2·20	2·50	.....	.....	.....
12.....	...do	1·34	1·79	2·16	2·51	2·81	.....	.....	.....
10.....	...do	1·55	2·18	2·55	2·89	3·17	.....	.....	.....
11.	...do	1·56	2·06	2·50	2·91	3·32	.....	.....	.....
Mean .	...do	1·38	1·89	2·27	2·63	2.95	.....	.....	.....
13.....	360°, 1h	1·70	2·54	3·12	3·56	3·86	4·15	4·42	4·70
14.....	...do	1·90	2·68	3·15	3·51	3·82	4·14	4·42	4·70
Mean .	...do	1·80	2·61	3·13	3·53	3·84	4·14	4·42	4·70
16.....	450°, 1h	2·03	2·74	3·20	3·57	3·91	4·23	4·52	4·80
15.....	...do ...	1·98	2·78	3·42	3·92	4·37	4·75	5·08	5·34
Mean .	...do	2·01	2·76	3·31	3·75	4·14	4·49	4·80	5·07
19.....	1000°	1·36	2·06	2·64	3·12	3·55	3·93	4·20	.....
21.....	...do	1·78	2·50	3·10	3·62	4·07	4·45	4·72	.....
18.....	...do	1·94	2·74	3·32	3·81	4·20	4·47	4·69	.....
20.....	...do	1·95	2·75	3·36	3·90	4·35	4·74	5·05	.....
Mean .	...do	1·76	2·51	3·10	3·61	4·04	4·40	4·67	.....

All radii identically $2\rho = 0{\cdot}082^{cm}$. Like signs of ($\phi-\phi'$) and of N refer to the same angular direction.

The results of Table 40 are graphically constructed in Fig. 20, time in hours as abscissa, difference of angular detorsion ($\varphi-\varphi'$), in radians, as ordinate.

33. *Immediate results.*—Table 40 and Fig. 20 lead to this curiously remarkable result: If we abstract for the moment from the states of temper extreme hard and extreme soft, *the viscosity of steel decreases in proportion as the hardness of the metal increases.* We call to mind here that the torsion imparted was not sufficiently large to produce marked permanent set (cf. Chapter III). If we express its intensity by $(0{\cdot}4E)\frac{\pi\rho^4}{2l}T$, and introduce the constants of the apparatus

$$T=\pi,\ l=20^{cm},\ 2\rho=0{\cdot}082^{cm},$$

we find that the moment of the applied torsion couple did not exceed 0·5 kg. on centimeter of arm. (Cf. remark on stress value, p. 48.) If, following Sir William Thomson,[1] we agree that "the molecular friction

[1] Thomson: loc. cit., or Thomson and Tait, Natural Philos., 1883, vol. 2, p. 303. Our present conception of the viscosity of liquids, as well as the hypothetical proportionality of frictional resistance *and velocity were introduced* by Newton (Principia, Liber 2, sect. 9, "*resistentia quæ oritur ex defectu lubricitatis*").

in elastic solids may properly be called viscosity of solids," then our deduction may be stated, *the molecular friction in case of steel is greater in proportion as the metal is softer.*[1] Examples of such relations in divers substances are not unknown. Hard steel as regards viscosity and hardness may be typified by sealing-wax; soft steel by tallow.[2] Nevertheless the continuous variations of these properties exhibited by steel is as unique as it is striking. Indeed we felt diffidence in reporting this result and have taken pains to substantiate it.

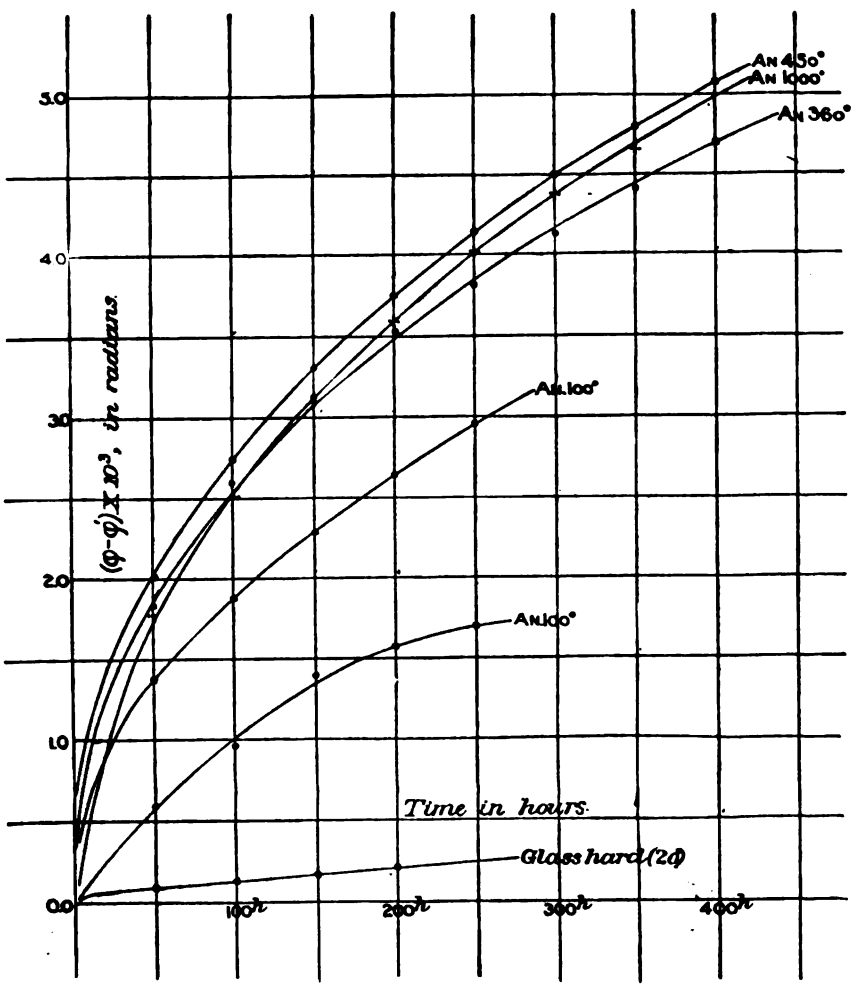

FIG. 20.—Viscous deformation of steel, as related to temper.

[1] Degrees of thermo-electric hardness are here specially in place. Cf. Bull. U. S. Geol. Survey, No. 14, p. 65.

[2] These examples (tallow, sealing wax) are given by Maxwell: Heat, Appleton, New York, 1883, p. 206.

34. The motion of the bifilar body of the above apparatus can be interpreted from two standpoints: Either it is due to the torsional couple and the result of viscous yielding of the harder wire relatively to the softer; or it may be due to the bifilar and flexural couple and is then the result of viscous yielding of the softer wire relatively to the harder (page 29). But the bifilar and flexural couples have been proved to be zero and to produce a zero effect. Hence the inference above italicized is alone admissible. Again, in the bifilar apparatus where steel is twisted against glass (Table 23) the soft steel is demonstrably more viscous than glass. Hard steel, as shown by its behavior with the same fiber, is less viscous than soft steel. We do not wish to say that it is less viscous than glass because the sectional area of the latter fiber is larger. Again, in Table 38, which contains the data obtained with the tubular apparatus, soft steel yields viscously at about the same rate as the brass tube of more than *four* times the sectional area of the steel wire. Hard steel under the same circumstances yields at a very much greater rate than brass.

35. Our results for degrees of hardness higher than "Annealed at 100°, 10^h" are to be regarded incomplete because of the magnetic importance of those degrees. As steel passes in hardness from "Annealed at 450°" to "Annealed at 1000°" (soft), it probably marches through maximum viscosity. This result is pretty clearly indicated by Table 40 and Fig. 20. Here also the results are to be regarded incomplete because of the magnetic importance of the (soft) degrees of hardness in question. Our methods of annealing between 500° and 1000° are not as yet satisfactory. It will be shown below that all remarks here made refer to intensities of stress less than the value (0·5 kg., cm.) given at the outset of this section. (Cf. Chapter II.)

36. *Viscosity and electrics of steel.*—If we compare the results of Table 40 or of Fig. 20 with the known thermo-electric behavior[1] of steel wires, we detect a very striking similarity in contour and position of corresponding members of the viscous and thermo-electric families of curves. Both phenomena practically subside in the first phase of annealing; the effect of temperature becomes rapidly less as higher degrees are approached. The same relations hold between viscosity and electrical resistance of steel.

37. *Viscosity and hardness.*—The relations between hardness and viscosity here encountered may perhaps be conceived somewhat as follows: Suppose stress to be so distributed in a solid that its application at any interface is nowhere sufficient to produce rupture. Then that property of a solid in virtue of which it resists very small forces (zero-forces) acting through very great intervals of time (∞-times) may be termed the viscosity of the solid. That property in virtue of which it resists the action of very large forces (∞-forces relatively) acting through zero-time may be termed the hardness of the solid. Since the application of

[1] U. S. Geol. Survey, Bull. 14, pp. 54, 55.

forces in such a way as accurately to meet either of these cases is rare, we have in most practical instances mixtures of viscous resistances and hardness to encounter. We may reasonably conceive that in the case of viscous motion the molecules slide into each other or even partially through each other by interchange of atoms, so that the molecular configuration is being continually reconstructed; that in the other case (hardness) the molecules are urged over and across each other and that therefore the intensity of cohesion is in this case more or less thoroughly impaired. In most cases of scratching, the action is indeed accompanied by physical discontinuity of the parts tangentially strained. The interpenetration of the molecules of a viscous substance is necessarily favored by temperature. Hence we infer the experimental result that the viscous influence of temperature is marked. If Clausius's theory of electrolysis be correct, then a certain instability or imperfect uniformity in the molecular structure of solids follows at once from the fact that many solids, notably glass,[1] may be electrolyzed even at moderately high temperatures (300°). The important bearing of all these remarks on Maxwell's theory of viscosity of solids will be given in Chapter III.

38. *Residual phenomenon.*—The stored torsional stress imparts a strain to the solid. Viscous detorsion therefore is accompained by a residual phenomenon. The observed deformation will continue until the applied tendency to change of form is reduced in value to the evoked and increasing tendency against change of form. If the applied stress be removed, the reciprocating stress becomes apparent and produces viscous effects of its own kind, as Kohlrausch has shown. The result has many magnetic and electrical analogies, among which the phenomenon of residual static charge is most obvious. In the tubular apparatus (Table 38), the residual deformation of the preceding twist may be superimposed on the deformation immediately in progress. Whether the two residual phenomena here annul each other so that the primary detorsion only is exhibited remains to be seen.

In liquids there is no such reaction unless it be the reciprocating force of galvanic polarization. In polarization, however, the mechanism is of an obviously chemical kind. In solids it is believed to be not chemical.

SECTIONAL AREAS OF BIFILAR WIRES.

39. The essential peculiarity of the bifilar apparatus is this, that the two wires are twisted by identical couples.[2] The absolute value of these couples during the experiment remains constant to 2 or 3 per cent. If the sectional areas of the wires be identical our apparatus leads to re-

[1] Warburg: Wied. Ann., vol. 21, 1884, p. 622. Literary notes are there given. Warburg is able to replace ⅓ of the sodium of glass by sodium of the anode.

[2] Many years ago we compared the longitudinal resilience of hard and soft steel by fastening one end of thin wires in a vise and bending them with a weight applied at the other. We found but insignificant differences. Hence the stored torsions of two steel wires, hard and soft, produced by equal couples are cæteris paribus of equal angular value.

sults which come very close to Newton's definition of viscosity. Newton suggested that the internal friction of liquids is cæteris paribus directly proportional to the difference of velocity between nearly contiguous surfaces. In the bifilar apparatus the torsional viscosities of two substances are equal if for identical strains and equal sectional areas torsional change of form occurs at like rates per unit of length. This is the condition of rest or zero-motion of the suspended body. Such inferences as are here given must, however, be drawn with extreme caution. There are certain cardinal differences between solid and fluid viscosity, which will be indicated in Chapter III and which must first be decided upon as prerequisites to conclusions like the present. It is doubtful whether Thomson and Tait's definition of solid viscosity can be at once accepted.

We do not at present wish to do more than advert to an important deduction here; it is obvious that if the sections of the wires be so chosen that the motion of the bifilar body is zero, the viscosity of the wires must be inversely related to those sections. This principle apparently enables us to arrange solids in a scale of viscosity. We may formulate it approximately thus:

Consider an elementary ring of either wire, whose height is dz and whose right sectional area is $2\pi r dr$. Let df be the amount of tangential force uniformly distributed over this area. At the time t let the velocity of the upper surface relatively to the lower be cr, where c is a time-function and cæteris paribus a characteristic of the viscosity of the wire. Then if μ_t be the coefficient of viscosity at the time t we have

$$df = \mu_t \frac{cr 2\pi r dr}{dz} = 2\pi\mu_t \frac{cr^3}{dz} dr$$

If we multiply by r and then integrate between zero and ρ (thickness $= 2\rho$), the numerical result is the part of the impressed torsional couple which corresponds to the length dz. A similar integral holds for the other wire, to distinguish which it is merely necessary to accentuate f, μ_t, c, r, ρ. The sum of the two integrals is zero. If, moreover, we put $c = c'$ in view of the state of rest of the bifilar body, we find that the viscosities (μ_t, μ'_t) of the two substances (wires) are to each other inversely as the squares of the respective sectional areas by which the motion of the bifilar suspension is annulled.

40. Unfortunately the problem is much more complex than it here appears. The dependence of torsional deformation on time in case of a single wire is obviously related to the character of the molecule. When two different substances in wire form are twisted bifilarly against each other, the effect will rarely be such that the torsional yieldings continually equalize each other, no matter what relations of section may be chosen. The motion-curve of the bifilar-suspension will show maxima or even points of circumflexion, such as have been actually encountered in Tables 23, 24, 25, etc., and the definition of relative viscosities of the *two wires will become* correspondingly involved. Apart from these

complications which are inherent in solid structure, a modification of the apparatus such as is given in Chapter II, or the present tubular apparatus, may easily subserve the purpose of classification by initial tangents.

41. Again, μ, for solids is not merely a function of time but very essentially a function of stress. Above we show (page 12) how by simply adjusting the lengths of the bifilar wires, viscosities may be compared at a given temperature, as time-functions with identical values of the parameters stress, strain (sectional area). We do not believe that viscous detorsion in this full relation has ever been rigidly investigated. The results would lead to families of curves.

Given a quadrifilar arrangement of four viscously identical wires. Let the twist T_{12} be stored between any two of them and then let the twist $T_{12,34}$ be additionally stored between these two as one, and the third and fourth wire as one. Such a device enables us in the above way to study viscosity in its simple dependence on strain, for all values of stress.

VISCOSITY AND STRAIN.

42. *Steel and glass.*—When we commenced the present research a comparison of the viscosity of glass and steel appeared desirable. In Tables 22, 23, such comparisons have been attempted, though we regret that the limitations of our available time have restricted our pursuit of them. In Table 22, the sectional area of glass fiber is less than that of steel wire; nevertheless the viscous yielding of the fiber is so much more rapid than that of the wire, that we may reasonably infer degrees of viscosity of the same order in the two substances. In Table 23, the sectional area of glass exceeds that of steel. Hence these data prove that the torsional viscosity of annealed steel is greater than that of glass. The viscosity of hard steel during the first ten hours of detorsion is certainly very much greater than that of glass. During the remainder of the time it is decidedly less. The curve passes through a maximum for which point the rates of viscous detorsion of glass and of glass-hard steel exactly coincide. Since the sectional area of glass is greater, we safely infer that the viscosity of glass is not uniformly greater than that of glasshard steel. It is well to call to mind, however, that the sum of the torsions is here only $T_s+T_g=90°$. Moreover, since for equal couples and dimensions $E_gT_g=E_sT_s$, where E is Young's modulus[1] of resilience for glass and for steel respectively and T the corresponding torsion; and since $E_g/E_s=1/3$ approximately, it appears that $T_g=3T_s$ nearly. Hence for equal stresses, strains are thoroughly unequal, and in the same measure are these comparisons not thoroughly just.

43. *Steel and iron.*—A similarly important desideratum is the comparison of the viscosities of steel and of iron. In Tables 24, 25, 26,

[1] To obtain an estimate it is sufficient to accept the same ratio of modulus of torsion to modulus of longitudinal resilience *for each case*. *Poisson's ratios* for glass and steel are about as 25 to 30.

etc., such comparisons are made, though further results are not superfluous. It appears distinctly that during the first five or ten hours of detorsion the viscosity of iron is in a strikingly pronounced manner less than that of steel. As detorsion continues the viscosity of soft iron continually remains below that of steel, whereas the viscosity of drawn iron grows temporarily greater than steel but finally reaches the same value. In this case the motion-curve passes through an exceedingly sharp maximum, at which the viscous yielding of iron and of steel occurs at like rates. Having exhibited greater viscosity in drawn iron it finally, by circumflexion, merges into a horizontal asymptote, which probably indicates subsidence of motion in each wire. These unexpected results show that the viscosity of steel is not uniformly greater than that of iron. Obviously glass-hard steel for the given stress is very much less viscous than iron.

The sum of the twists is here nominally $T_s-(-T_i)=360°$. Particularly in the case of soft iron its efficient value is very decidedly less, however. The applied torsion carries the iron wire much beyond the limits of elasticity; and so much of the stress vanishes instanter that the "after-action" subsides within relatively small limits. The viscosity of (soft) iron is either less or greater than that of hard steel according as the applied torsional stress surpasses or falls below a certain critical value. This result again shows the importance of stress-measurement, as a means of coordinating the lingering of purely viscous deformation and the instantaneous (?) deformation.

In the above results the curvature of the (absolute) motion curve for a *single* wire increases uniformly from hard steel to soft steel; increases, moreover, from soft steel to iron. Curvature is greater in the glass curve than in hard steel curves. So far as we have observed (steel, iron, glass) viscous deformation occurs more nearly at uniform rates (linearly) in proportion as hardness is greater. Cf. Chapter III, where similar results are given under "accommodation." Curvatures for early time are meant, the later parts of curves being asymptotes.

44. *Effect of quenching.*—The remarks just made on the viscosities of glass and iron suggest this plausible inference: if glass and steel be alike subjected to a stated process of quenching, and if after the operation has been performed glass be found to have retained a very high intensity of strain (Rupert's drop), then, a fortiori, steel, the substance of greater viscosity, must have retained a similarly high intensity of strain. This reasoning, however, is incomplete and must be approached with caution. We pointed out[1] that the low degrees of thermal conductivity possessed by glass were favorable to the retention of strain. We also remarked[2] that the occurrence of Gore's phenomenon of sudden expansion at red heat distinguished iron and steel from all other metals, and that in spite of relatively good thermal conductivity, iron and steel

[1] Am. Jour. Sci. (III), 1886, vol. 31, p. 451.
[2] Bull. U. S. Geol. Survey, No. 14, p. 99.

possessed virtually all the favorable conditions of glass for retaining strain. Whether differences of viscosity are sufficient to account for the unlikeness of behavior during quenching we are unable to say. It will be necessary to compare iron and steel at higher than ordinary temperature and also under greater values of applied stress than was easily feasible in the above experiments. In other words, iron and soft steel are nearly equally viscous for small values of stress. After stress exceeds a certain intensity, the permanent set suddenly imparted to iron is enormously great as compared with steel. Similar relations are true for soft steel when compared with hard steel. It is this class of "sudden" phenomena which come into play during quenching. The primary effect of quenching steel is chemical hardness. Strains are retained in the steel so modified, just as they are in glass; whereas in soft steel or soft iron the result would be permanent set. In Chapters II and III, a more complete explanation than is here possible will be given, so that further consideration may be waived for the present.

The occurrence of sudden and gradual deformation in a single substance suggests that ordinary *static* friction is probably a viscous phenomenon.

45. We add in passing that the observed inefficiency of temperatures less than 200° in producing marked viscous deformation in a Rupert's drop proves that mere interference of thermal expansion with the conditions of strain cannot be the primary cause of its variations; that strain variations essentially depend on diminished viscosity.

46. *Steel and cast-iron.*—We also add in passing that the importance of strain as associated with glasshardness is emphasized by the mass-constants of the cast-irons. The densities of these metals[1] range between the maximum of ca. 7·6 for white cast-iron and the minimum of ca. 6·9 for gray cast-iron. Hence density increases in marked degree in proportion as total carbon is more and more nearly combined. Quite the reverse of this is true for steel where density decidedly decreases as total carbon is more and more nearly combined. This discrepancy we interpreted as a strain of dilitation and carefully compared it with the analogous behavior of glass in our earlier papers.

47. *Stress intensity estimated.*—We add finally the following data from the elastics of glass and of steel. The æolotropic expansion produced by quenching glass or steel we showed elsewhere[2] to amount to 0.005. The volume resilience of glass and of steel, according to Professor Everett's measurements,[3] is 4×10^{11} and 2×10^{12} respectively. Hence if per square centimeter p be the stress-value for the given expansion, we find approximately $p=10\times10^{9}$ dynes for steel and 2×10^{9} dynes for glass. Now per square centimeter the tenacity of steel is 8×10^{9} dynes; the tenacity of glass $0{\cdot}6\times10^{9}$ dynes. The approximate ratio of stress to

[1] Cf. Bloxham's Chemistry, Lea, Philad., 1873, p. 342. Bull. U. S. Geol. Survey, No. 14, pp. 76, 77.

[2] Am. Jour. Sci. (III), 1866, vol. 32, pp. 190, 191. By æolotropic expansion we refer to the part of the total expansion which produces explosiveness and the polariscopic phenomenon.

[3] Everett: Phil. Trans., *1866, p. 369.* The above numbers are rounded from Everett's values.

tenacity is therefore estimated at 1·3 for steel and 3·3 for glass. This shows that in both cases stress and tenacity are of the same order; that stress is in excess; that but for the peculiarly favorable, symmetrically arched structure of the quenched globule, rupture would ensue in glass certainly; probably also in steel. This accords with the explosive tendency of a Prince Rupert's drop and with the less pronounced liability of steel to crack on quenching.[1] If therefore quenched glass and quenched steel are under mean stress intensities of several thousand atmospheres, then in discussing the corresponding viscous properties they must be brought into relation with these high values of peculiar stress.

MAGNETIC RELATIONS.

48. *Viscosity and magnetic intensity.*—If again we abstract from the extreme states of hardness, we find that both the viscosity and the moment of linear magnetization per unit of mass, of a permanently saturated steel rod, increase in marked degree from hard to soft. This is a singularly striking result, inasmuch as the conditions of magnetic stability (following Hopkinson we shall call them coercive force), conditions which at first sight we would be inclined to associate with viscosity, decrease as viscosity increases. Hence permanently saturated linear magnetic intensity and viscosity on the one hand, magnetic stability or coercive force and hardness on the other, seem to belong together.

49. *Magnetic and viscous maxima in steel.*—The minimum of permanent linear intensity of saturated steel rods has no viscous equivalent; but we have not yet studied the viscosity of extremes of hard steel minutely, nor have we as yet sufficiently sharp data for the magnetization of very long rods (length /diameter >100) in its relation to temper. In the extreme soft region, on the other hand, the occurrence of a unique maximum of magnetization seems to be coincident with the occurrence of maximum viscosity. The magnetic maximum so far as our results go is apparently much more clearly pronounced than the viscous maximum. We remark in general that as the ratio of length to diameter increases, the minimum of permanent magnetization shows a tendency to move from soft to hard. Furthermore, it is proved that the permanent magnetization of soft rods is greater in proportion as they are more and more nearly linear.[2] Hence as our march approaches the linear limit we observe an unmistakable tendency toward more detailed similarity between the variations of the magnetic and the viscous properties of steel.

Mr. Hopkinson[3] in his memoir on the magnetization of iron introduces a definition of coercive force, defining it as "that reversed magnetic force which just suffices to reduce the induction to nothing after the

[1] Mr. J. M. Batchelder has just communicated to us his interesting results (Jour. Franklin Inst. (3), 1884, vol. 8, p. 133), in which of twelve massive pieces of quenched steel, eight subsequently cracked and one actually exploded.

[2] Bull. 14, U. S. Geol. Survey, pp. 140 to 143.

[3] *Hopkinson: Phil. Trans.*, 1885, vol. 2, p. 463.

material has been subjected temporarily to very great magnetizing force." There is a slight objection to this definition, inasmuch as it introduces a somewhat vaguely complex state of zero-magnetization.[1] Wiedemann[2] in comparing magnetization to and fro with viscous torsional accommodation has been most explicit on these points. But the feature in question is hard to improve and the definition is valuable. Mr. Hopkinson's extensive experiments show that coercive force is invariably increased by hardness. Together with others we have proved that hard steel is alike well adapted to withstand the influence of percussion.

50. *Steel and iron.*—These general relations between viscosity and maximum permanent linear intensity observed for steel are sustained by iron. According to data contained in a paper of the lamented Dr. L. M. Cheesman[3] the permanent magnetization of drawn iron exceeds that of soft iron. The magnetic intensity of permanently saturated drawn iron is comparable with that of soft steel and quite equal to that of hard steel. More recently and even more elaborately Ewing has discussed the subject. He finds "in the absence of mechanical or other disturbance, soft iron is far more retentive than either hard iron or steel," an exceedingly remarkable result.[4] Our experiments show that the intensity of applied stress is an important factor in determining the viscous behavior of iron; that for moderate stress values it *ultimately* approaches very closely or even exceeds the maximum viscosity of steel; that it is much greater than the viscosity of hard steel.

REMARKS.

51. Among the results of this paper is the light thrown on the crucial importance of the physical changes which steel undergoes during annealing at high temperatures, i. e., when subjected to the action of temperatures between 500° and 1000°. Prof. W. F. Barrett,[5] who made valuable researches on this subject, pointed out the more important coincidences (elongation, crepitation and ticking, recalescence, magnetic and thermo-electric anomalies). In our our earlier work we unfortunately overlooked these papers. Tait, however, had before this connected his peculiar iron line (thermo-electrics) with Gore's phenomena. The occurrences in question may now be summarized as follows: Gore's[6] sudden

[1] The unmagnetic state, though dependent on the details of the process of tempering, is a distinct magnetic state. Similarly we may regard the saturated magnetic state, though allowance must here be made for the occurrence of cyclic magnetization, a phenomenon suggested by Fromme (Wied. Ann., 1878, vol. 4, p. 89) and (Wied. Ann., 1881, vol. 14, p. 308), concisely, interpreted by Warburg (Wied. Ann., 1881, vol. 13, p. 141) and which Ewing (Phil. Trans., 1885, vol. 2, p. 545) has recently discussed generically under the name of "hysteresis."

[2] Wiedemann: Wied. Ann., 1879, vi, p. 512.

[3] Cheesman: Am. Jour. Sci. (III), 1882, vol. 24, p. 183. Lengths 100 diameters and less.

[4] Ewing: op. cit., p. 541.

[5] W. F. Barrett: Journal London Inst., July, 1873; Rept. Brit. Assoc., 1875, vol. 45, pp. 259–60; Phil. Mag. (5), December, 1873; ibid, January, 1874; Proc. Royal Dub. Soc., 1886; Am. Jour. Sci. (III), 1887, vol. 3, p. 303. For recent work on recalescence see Hopkinson: Proc. Roy. Soc., 1889, vol. 45, p. 455.

[6] Gore: Proc. Roy. Soc., 1869, vol. 17, *p. 260.*

volume expansion; Tait's[1] sinuously broken thermo-electric diagram-line; Barrett's (loc. cit.) recalescence, crepitation, and elongation phenomena; Barrett's behavior of manganese steel; Gore-Baur's[2] sudden disappearance of magnetic quality; the passage of carbon from uncombined to combined; Jeans's[3] critical cementation temperature. Further, Chernoff-Barus's[4] sudden appearance of hardness in quenched steel, Fromme's[5] maximum density, Chwolson's[6] minimum resistance, our own unique maximum of magnetization[7] and probable maximum of viscosity, Howe's[8] sudden decrease of rigidity, are all referred to this interval, approximately to the same temperature. To determine the interdependence of these phenomena it is obviously first necessary to devise methods of operating on steel adapted to the interval in question. In other words, our introductory problem is the annealing of steel without oxidation and without carburation, at measured (high) temperatures, during stated times. It is in this direction that our investigation will ultimately proceed. In the present work, however, the thermal relations of viscosity still command paramount attention; and their importance gains much when it is called to mind that before a satisfactory physical theory of viscosity has been formulated, the light which data like the above throw on ulterior electrical phenomena will not be searching.

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[1] Tait: Trans. Roy. Soc., Edinburgh, 1872–'73, vol. 27, p. 125.

[2] Gore: Phil. Mag., IV., 1869, vol. 38, p. 59; Baur. Wied. Ann., 1880, vol. 11, p. 408; Ibid., 1870, vol. 40, p. 170.

[3] Jeans: "Steel, its history, etc." London, Spon, 1880.

[4] Chernoff: Vortrag. geb. in der Russ. techn. Ges., April und May, 1878. Barus: Wied. Ann., 1879, vol. 7, p. 405.

[5] Fromme: Wied. Ann., 1879, vol. 8, p. 354. We were unable to find Fromme's maximum: but we will search again. All these results are crucially dependent on the method of annealing, as stated in the text.

[6] Chwolson: Carl's Repertorium, 1878, vol. 14, p. 26.

[7] Barus and Stroubal: Bull. U. S. Geol. Survey, No. 14, pp. 145, 198.

[8] H. M. Howe: Scientific American Supplement, April, 1889, p. 11055.

CHAPTER II.

THE VISCOSITY OF STEEL AND ITS RELATIONS TO TEMPERATURE.

INTRODUCTION.

52. This chapter is to be restricted to a discussion of the relation between torsional viscosity and temperature, as observed with steel in different states of hardness. Some mention of the effect of stress on the amount of viscous motions in solids is, however, unavoidable; and the experiments lead naturally to the investigation of a more general method, by which the instantaneous deformation and the gradual deformation produced by stress may be coordinated. The data already show that imperceptible gradations lead from the purely viscous deformation which follows strains within the elastic limits, to the sudden, permanent set which follows strains beyond the elastic limits. As a whole the data bear directly on the truth of Maxwell's theory of viscosity. (Cf. Chapter III.)

METHOD OF MEASUREMENT.

53. *Apparatus.*—Instead of countertwisting two wires suspended bifilarly, as was done in Chapter I, it is for many purposes preferable to suspend and twist them unifilarly. In this case they may be kept at different temperatures throughout different parts of their lengths, and the adjustment therefore has special advantages for the class of experiments indicated in the present chapter.

In the actual work it is expedient to compare two identical wires, one of which is kept hot, the other cold. These wires are shown in the annexed diagram (Pl. I) at *ab* and *cd*. The ends, having been bent loop-shaped, are screwed near the middle of the apparatus to a cross-piece of iron carrying the adjustable mirror M. This is the index referred to in the preceding paragraph, and angular deviations are read off by Gauss's method. To deaden lateral vibrations the mirror is also provided with a cross-vane, *mm*, dipping appropriately into a fixed dish of water. In later experiments this dish was replaced by an annular vessel surrounding the wire. The upper end of the system of wires is screwed to a round steel rod, *af*, which fits snugly in the perforation of the massive fixed piece of brass *gh*. A steel pin, *p*, passing through both brass and steel rod, secures the latter to the former. The lower end of the wires is similarly fastened to the steel rod *dk* and the fixed

piece of brass *kl*. To keep the wires tense they are stretched by a weight, RQ; and a part of the lower fixed brass *kl* has therefore been cut away in such a manner that the lower pin *q* may slide along a plane. The system of wires is therefore free to expand.

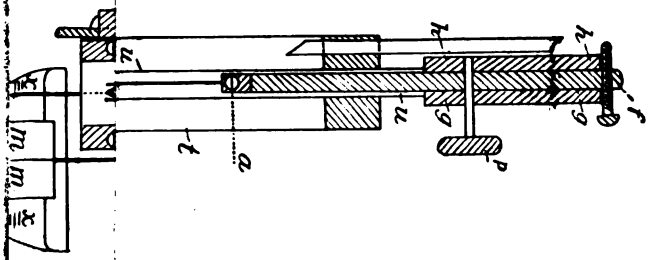
To heat the upper wire, a given part of it was surrounded by a special form of vapor bath, without being necessarily in contact with it. This has been described elsewhere.[1] Steam (100°), aniline vapor (190°), and mercury vapor (360°) were consecutively introduced, and errors due to radiation were carefully avoided by appropriate screens.

The vapor bath mentioned is seen in the figure at *ttt*, being a boiling tube containing the liquid whose boiling point is to be utilized and surrounded at its lower end by the ring burner *rr*. The asbestus screen *ss* protects the upper end of the tube from direct radiation. It is desirable to bring as much of the wire within the central tube *uu* as possible. If necessary the upper end of this tube may be loosely closed with asbestus to obviate currents of air. By carefully regulating the ring burner there is no difficulty in maintaining ebullition for hours.

By removing and then re-inserting the pin *q*, the wires may be twisted in multiples of 90° for each length, or in multiples of rate of twist (τ) of 3° for each wire. For the given dimensions this is the effect of a couple of 250 g. on one centimeter, for each 3° of rate of twist. In later forms of this apparatus a divided circle was attached to the lower piece *dh*, thus enabling the observer to vary the value of τ and to measure the amount of permanent set at the end of the experiment.

54. A few critical remarks on the efficiency of the apparatus are in place. In most of the experiments made the torsional deformation is so great that special fiducial marks to register the possible motion of the fixed pieces *gh* and *kl* are superfluous. Indeed, for angles as large as those observed, Gauss's method of angular measurement is no longer conveniently applicable, because of the number of corrections which become essential, and in future measurements it will be expedient to use other methods. The large deflections, however, made it possible to use the Gauss method even when the apparatus is thrown into unavoidable vibration; for instance, when the upper wire is surrounded by boiling mercury. In the present work it did not seem necessary to take special precautions for jacketing the lower wire. Its temperature is that of the surrounding air, very nearly, and it is not heated by radiation. In the case of steam and of aniline vapor, the length of the hot part of the upper wire is sharply measurable, but in the present work this could not be so satisfactorily done for mercury vapor. Regarding the mode of heating, there are two methods available: the wire may either be heated and the twist then applied, or the wire may be twisted to the desired amount before heating. The former of these methods eliminates the time error, but it is difficult to obtain an accurate reading for the zero-point, i. e., the scale reading for the twisted system before

[1] *Bull. U. S. Geol. Survey No. 54, p. 86 et seq., where the form of boiling tube used is fully given.*



PARATUS.

heat is applied. Hence the other method was adopted, in which the invariability of the zero referred to can be satisfactorily tested before each experiment. The error is the time consumed in heating the wire, and in the second part of the observation, the time consumed in cooling the wire after heating. Special means for cooling were not applied. When the motion is great, it is desirable to have the index-mirror adjustment light, though the device used was not perhaps objectionably heavy.

The immediate effect of heating the upper wire is an expansion of the system. Hence if the part of the lower fixed brass cylinder *kl*, along which the pin *q* is free to slide, be not plane and true, there will be a tendency to rotate the system. If, however, the twist be alternately applied positively and negatively, this expansion error is eliminated by commutation. This safeguard was invariably applied. When the twist stored amounts to 180° for each wire, its sign may often be reversed and readings may be made without necessarily readjusting the mirror. For smaller twists the mirror must be readjusted. Larger twists were not applied because of liability to permanent set of the wire so twisted.

55. The wires used are Stubs's best steel, hardened and tempered electrically, as described elsewhere.[1]

A few words relative to the technical terms used to designate the temper of steel may here find place. Prof. Roberts-Austen[2] has endeavored to give definiteness to the notation by proposing that the operation by which steel is made as soft as possible (heating to redness with very slow cooling) be termed "annealing"; whereas operations by which any other degree of hardness between extreme hard and extreme soft is imparted to steel, be termed "tempering". From a physical point of view I see little importance in such a distinction, except perhaps that under annealing *exceptionally* slow cooling is implied—i. e., to anneal steel, it is essential to cool the hot metal much more slowly, than is usually necessary in tempering. Otherwise an extreme of soft state will not be obtained. In general, however, since in any case of tempering it is necessary to act on a rod of a higher degree of hardness than the one to be produced, it makes little difference whether the rod be described as having been tempered at a temperature x, during a time y, or annealed at a temperature x, during a time y. Sufficiently slow cooling after the heating is evidently and always understood. In short the whole process is continuous in character, and a rod tempered at red heat is virtually annealed. Hence in the present work I have not thought it needful to discriminate between annealing and tempering, and I use the words interchangeably.

56. *Theory of the apparatus.*—In a general way the theory of this apparatus is similar to that given in Chapter I, § 31. There are special points however to which it is necessary to call attention specifically. In

[1] Cf. above, Chapter I, § 8 et seq. Also Bull. U. S. Geol. Survey, No. 14, 1885, p. 29.
[2] Nature, vol. 41, 1889, pp. 11, 42.

the bifilar suspension the twist helices of the two wires were right handed and left handed respectively. In the present instance the sign of the twist is the same throughout its length. Given a continuous straight steel wire of length L, to which a convenient rate of twist, τ, has been imparted. Consider two right sections whose distance apart is the unit of length, and let 2φ be the amount of viscous angular motion of the first relative to the second, during the given small time t, for the stated rate of twist τ. To fix the ideas, let the wire be adjusted vertically, and provided with an index to register angular motion at a distance l' above the lower end. At every section the viscous motion is such, that if the contiguous parts immediately below the section slide in a given direction, the parts immediately above it slide, in equal amount, in the opposite direction. Again, of the two equal and opposite viscous motions which take place on any section, only the part nearest the index will influence it. Finally throughout the whole viscous detorsion the twist is kept constant throughout the wire in virtue of its elasticity.

In Fig. 21 I have developed the conditions which here obtain, on a plan similar to that described in § 31. The length of the two wires A and A', is shown at $fd=l'$ and $da=l$, respectively, so that $af=l+l'=L$. Again $gf=T\rho$, where T is the twist for the length L and ρ the common radius of the wires. Hence gf is small as compared with af. The developed position of the twisted fiber is shown at ag, so that tau gaf is the twist $T=L\tau$. Virtually af and ag are equal in length and the position of the index is at d or the corresponding point of junction b.

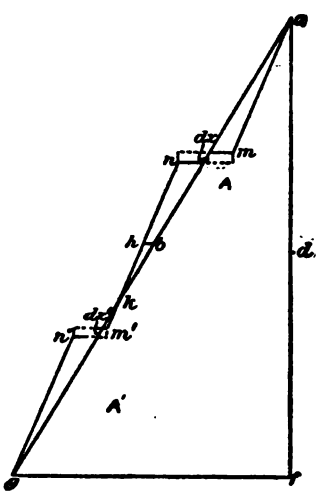


Fig. 21.

Consider the viscous sliding which takes place on the two end faces of the elementary cylinders dx and dx', distant x and x' respectively from the lower end of the system. Then in a very short time, the originally straight fiber abg is changed to a broken line $amnh$, $hm'n'g$. Here $mn=2\varphi dx$, $m'n'=2\varphi' dx'$, and $bh=d\psi$. If k be the point of intersection of the broken line $amnm'n'g$ and the straight line ag, let $bk=y$. Then an inspection of the diagram shows

$$\frac{2\varphi dx}{d\psi}=\frac{l+y}{y} \text{ and } \frac{2\varphi' dx'}{d\psi}=\frac{l'-y}{y} \quad \ldots\ldots (1)$$

If for y its geometrical value in terms of L, l, x, x', etc., be inserted, and if for brevity $2\varphi dx=a$ and $2\varphi' dx'=a'$, the following relation results:

$$\frac{a-a'}{d\psi}=\frac{2(L+x-x')-L(a+a')/a}{L+x-x'-l(a+a')/a} \quad \ldots\ldots (2)$$

Unfortunately this is too complicated for use except where $L=2l=2l'$, or where the two wires of the system are of equal length with an index at the point of junction. In this case $\varphi dx-\varphi' dx'=d\psi$ . . . . . (3)

57. This premised, the conditions of experiment may at once be introduced. Let the parts of the wire below the index, the parts whose position is 0 to l' be kept at a given constant temperature, and be of the same temper throughout. Also let those parts of the system above the index be of the same, or any other uniform temper; but suppose them heated to different constant temperatures. Thus let the viscous detorsion between $x=0$ and $x=l'$ be $2\varphi'$; between $x=l'$ and $x=\beta$ be $2\varphi_3$; between $x=\beta$ and $x=\alpha$ be 2φ; between $x=\alpha$ and $x=L$ be $2\varphi_1$. The differences φ_1, φ, φ_3 are evoked by differences of temperature of the parts of the wire to which these data refer, whereas φ' may differ from all of these by an increment of temper as well as of temperature. Then the influence of the viscous detorsion in each of the parts in question on the index whose position is $x=l'$ will be in the aggregate

$$\psi=\varphi_3(\beta-l')+\varphi(\alpha-\beta)+\varphi_1(L-\alpha)-\varphi' l' \quad . \quad . \quad . \quad . \quad (4)$$

Equation (4) results at once from a suitable integration of (3).

In the present chapter $\varphi_3=\varphi_1=\varphi'$, since the tempers and temperatures of these parts are alike. Hence

$$\psi=(\varphi-\varphi')(\alpha-\beta) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

It will usually be convenient to put $\alpha-\beta=a$.

58. If a series of detorsions φ be observed at θ°, and another series, Φ, at Θ°; if $\varphi=\varphi_0 F(\theta)$ and $\psi=n\,/\,2R$ (Gauss's method of angular measurement), then $\varphi_0(F(\Theta)-F(\theta))=(N-n)\,/\,RL$, where R is the distance between mirror and scale in *cm* and where N and n are the scale parts (*cm*) corresponding to Θ° and θ°, respectively. Hence the distance of the individual curves for Θ° and θ° apart varies directly as φ_0. This result, though simple enough, has special bearing on the text below.

59. *Digression.*—In the interest of certain correction to be applied to some of my early results, I will inquire what correction is to be applied when the elastic restitution which accompanies viscous motion, is disregarded. In this case the differential equation corresponding to (3) is

$$d\psi=\frac{l'}{x}\varphi dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3')$$

and equation (4) is replaced by

$$\psi=l'\left(\varphi_1 ln\frac{L}{\alpha}+\varphi ln\frac{\alpha}{\beta}+\varphi_3 ln\frac{\beta}{l'}\right)-l\varphi' ln\frac{L}{l'} \quad . \quad . \quad . \quad . \quad (4')$$

Equation (5) finally by

$$\psi=l(\varphi-\varphi')ln\frac{x}{\beta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5')$$

Thus to reduce such data as are given in tables 42 to 51, if calculated by (5′) to data calculated by (5), the factor would be 0·66; for tables 52 to 54, the factor would be 0·78, etc., or in general $ln\alpha\,/\,\beta$.

EXPERIMENTAL RESULTS.

60. *Residual twist.*—The following experiments have an introductory and suggestive character. Two glass-hard wires with their ends bent loop-shaped are fastened firmly together at one end of each. The other ends are twisted τ° against each other and also fastened. This *twisted system* of glass-hard wires, or system in which a rate of twist of 3° or 6° has been stored, are then annealed at divers temperatures during stated times as shown in the tables. The amount of twist lost during annealing is measured by determining the angle between the planes of the upper and lower loops of each wire before and after annealing. A gallows arrangement by which a needle is suspended over a divided circle by the steel wire itself is used for measurement.

The tables contain the number, length (L) and diameter (2ρ) of the glass-hard wires used for each couple; also the temperature and the time (h) in hours, during which the couples are annealed. They contain, furthermore, the amount of viscous detorsion (Δ_1, Δ_2) or twist lost during annealing, for each of the times specified, and each of the wires; finally, the amount of twist stored in each wire of the system. This amount is equal to the twist nominally applied, minus the angle between the plane of the loops. Allowance is made for the amount of permanent set produced by mere manipulatory twisting of the cold wires. When this exceeds 10°, the Δ is discarded. The error of angular measurement is probably not greater than a few degrees.

In the second part of the table the wires S and T are soft.

TABLE 41.—RESIDUAL TWIST. RODS GLASS-HARD.

No.	Annealed at	h	Δ_1	Δ_2	Twist.
A and B $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	100°	0·00 1·08 2·08 3·58	0·0 57° 64 70	— — — —	180°—7°
C and D $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	100°	0·00 0·17 0·67 2·00	— — — —	—0·0 —36° —64 —70	180°—10°
E and F $L=31^{cm}$ $2\rho=0{\cdot}82^{cm}$	190°	0·00 0·10 0·80	— — —	—0·00 —123° —153	180°—25°
G and H $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	190°	0·00 0·10 1·00	— — —	—0.0 —104° —130	180°—2°
I and J $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	190°	0·00 0·08 1·20	0 89° 57	0 52° 69	90°—10°
K and L $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 166°	0 148°	180°—20°
M and N $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 180°	0 166°	180°—10°
O and P $L=31^{cm}$ $2\rho=0{\cdot}082^{cm}$	360°	0·00 0·30	0 77°	0 71°	90°—8°
Q and R $L=31^{cm}$ $2\rho=0{\cdot}043^{cm}$	360°	0·00 0·30	0 156°	0 165°	180°—8°
S and T $L=31^{cm}$ $2\rho=0{\cdot}043^{cm}$	360°	0·00 0·30	0 48°	0 54°	180°—2°

61. This table contains results which may be expressed as follows: the viscous detorsion produced by the action of any temperature on a twisted system of glass hard steel wires, increases at a rate gradually diminishing through infinité time, diminishing slowly in case of low temperatures ($<100°$), rapidly at first and then again slowly at high temperatures ($>200°$); so that the residual twist corresponding to any given temperature is reached asymptotically. Moreover, the strain carried by the glass-hard twisted system is almost completely annulled when the temperature at which annealing takes place exceeds 350°. These results are strikingly similar to the *thermoelectric effect*[1] produced by annealing glass-hard steel, that the present purely mechanical result may safely be used to interpret the electrical result: in both experiments we observe strains disappearing under like conditions.

The table contains another important result: by comparing the second part of the table with the first, it appears that the effect of temperature in decreasing the viscosity of steel is greater in proportion as steel is harder. For where the twist is stored between two glass-hard wires it is found to have almost completely vanished after annealing; but where the same twist is stored between two soft wires less than one-third of it has vanished after annealing. The curious inference that in so far as its viscous properties are concerned, steel is much more susceptible to temperature when it is hard than when it is soft, will be carefully discussed in the following pages by aid of the apparatus already described.

In Fig. 22 I have shown graphically the results reached by annealing twisted systems of glass-hard wires at 360°. The form of the wire before annealing is given at *C*, the shape being that of an elongated C. This same wire is then twisted to the form of an elongated *S* and then annealed in this twisted condition. After annealing, the cold wire will be found to be permanently S-shaped, all temporarily stored twist having vanished during the exposure. This shows that hard steel during the period of occurrence of the annealing in question, is almost a viscous fluid.

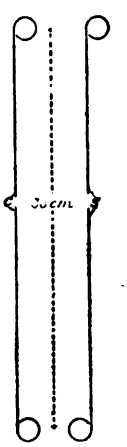


Fig. 22.

TORSIONAL VISCOSITY AND TEMPERATURE.

62. *Notation.*—The data of the following thirteen tables give a clear description of the viscosity of steel for temperatures between 0° and 400°, and for all degrees of hard ness. These data are readily intelligible. θ denotes the temperature of the hot part, θ' the temperature of the cold part of the wires in the apparatus (Pl. I). The distance between mirror and scale was 360^{cm} throughout. L, l, β, a, have the signification already given, being the total length of system of two wires, the distance of mirror

[1] Bull. U. S. Geol. Survey No. 14, 18. 5, pp. 55, 95.

above their lower end, the length of their cold and of their hot parts, respectively, in centimeters. Hence $a=\alpha-\beta$. The tempers of the rods (diameter 2ρ) are expressed by the temperature at which the originally glass-hard rod was annealed. Soft rods are annealed at red heat. The tabular arrangement contains the date and the time (h_0) in hours and fractions of an hour, of each of the angular detorsions ($\varphi-\varphi'$), in radians. 2φ has been defined, §§ 31, 56. It denotes the angular viscous motion between two right sections of the hot wire, whose distance apart is the unit of length, when the temperature of the included wire is θ° and the original rate of twist is τ for the given diameter 2ρ. $2\varphi'$ has the same meaning for the cold wire. Identical signs of τ and $(\varphi-\varphi')$ refer to angular motions in the same sense, and since τ and $(\varphi-\varphi')$ agree for the cold rod this is invariably of greater viscosity.

63. *Viscosity at* 100°.—The data in hand are given in Tables 42 to 47.

TABLE 42.

$\theta=100^{\circ}$; $\theta'=20^{\circ}$. $L=60^{cm}$. $l=30^{cm}$. $a=26^{cm}$. $\beta=34^{cm}$. Rods: No. 1, soft; No. 2, soft. $2\rho=0{\cdot}082^{mm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Feb. 18, 0h 53m	0·00	0·00	*	Feb. 19, 2h 44m	1·45	−1·30	Steam off.
				3 00	1·72	−1·16	
0 56	0·05	−1·04		25	2·13	− ·69	
1 00	0·12	−1·10		4 55	3·63	− ·63	
15	0·37	−1·22		24, 10h 42m	0·00	+0·00	‡
45	0·87	−1·43	Steam on.				
2 45	1·87	−1·61		10 45	0·05	·75	Steam on.
3 50	2·95	−1·81		59	0·29	1·06	
4 30	3·63	−1·97		11 12	0·50	1·16	
				27	0·75	1·20	
4 33	3·67	−1·85		59	1·30	1·26	
44	3·85	−1·56	Steam off.	12 23	1·66	1·28	
54	4·02	−1·46		1 15	2·50	1·30	
19, 9 30	20·67	−1 24					
19, 1h 17m	0·00	−0·00	†	1 22	2·65	1·08	Steam off.
				30	2·80	·89	
1 25	0·13	−1·14		50	3·13	·76	
56	0·65	−1·29	Steam on.	2 12	3·50	·67	
2 14	0·95	−1·35		3 30	4·80	·63	
40	1·38	−1·40					

* τ (cold rod) -6°, imparted after heating.
† τ (cold rod) -6°, imparted before heating.
‡ τ (cold rod) $+6^{\circ}$, imparted before heating.

TABLE 43.

$\theta = 100°$; $\theta' = 20°$. $a = 26^{cm}$. $l = 30^{cm}$. Rods: No. 3, ann'ld, 100° 9^h / No. 4, ann'ld, 100° 9^h } $2\rho = 0{\cdot}082^{cm}$. $L = 60^{cm}$. $\beta = 34^{cm}$.

Date.	h_θ	$(\phi-\phi')\times 10^3$		Date.	h_θ	$(\phi-\phi')\times 10^3$	
Feb. 24, 4^h 36^m	0.00	— 0·00	*	Feb. 26, 10^h 02^m	0·00	0·00	‡
4 43	0.12	— 3·03	Steam on.	10 10	0·13	— 7·97	Steam on.
45	0.15	— 3·75		15	0·21	— 8·84	
55	0.32	— 8·81		20	0·30	— 9·80	
5 10	0.57	—10·61		25	0·39	—10·42	
				30	0·46	—10·95	
5 15	0.65	— 8·21	Steam off.	44	0·70	—12·15	
25, 9 40	17.07	— 6·95		55	0·89	—12·86	
25, 10^h 00^m	0.00	0·00	†	11 04	1·03	—13·31	
				16	1·22	—13·89	
10 06	0.10	5·91	Steam on.	43	1·70	—14·89	
10	0.18	9·40		57	1·92	—15·38	
20	0.32	12·09		12 55	2·87	—16·80	
25	0.42	13·06					
30	0.50	13·41		1 09	3·10	—16·08	Steam off.
34	0.56	13·80		30	3·41	—15·64	
				55	3·88	15·56	
45	0.75	13·21	Steam off.	3 12	5·16	—15·16	
11 00	1.00	12·71					
28	1.47	12·47					
1 40	3.67	12·27					
26, 9 37	23.62	12·03					

* τ (cold rod) — 6° imparted before heating.
† τ (cold rod) + 6° imparted before heating, immediately after *.
‡ τ (cold rod) — 6° imparted before heating, immediately after †.

TABLE 44.

$\theta = 100°$; $\theta' = 20°$; $a = 26^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 5, annealed, 190°, 2^h; No. 6, annealed, 190°, 2^h; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_θ	$(\phi-\phi')\times 10^3$		Date.	h_θ	$(\phi-\phi')\times 10^3$	
Feb. 26, 3^h 57^m	.....	0·00	*	Feb. 28, 3^h 55^m	1·83	—6·86	Steam off.
4 15	0·00	0·00		4 05	2·00	—6·48	
				54	2·82	—6·12	
4 20	0·09	—3·22	Steam on.	Mar. 5, 10^h 20^m	0·00	0·00	*
25	0·17	—3·86		10 26	0·10	—1·59	Steam on.
34	0·32	—4·50		30	0·16	—1·95	
40	0·42	—4·79		35	0·25	—2·05	
51	0·60	—5·10		44	0·40	—2·16	
5 10	0·92	—5·50		56	0·60	—2·30	
5 17	1·03	—5·02	Steam off.	11 01	0·68	—1·93	Steam off.
28, 9 52	41·62	—3·84		06	0·76	—1·59	
28, 9^h 58^m	.....	0·00	†	13	0·88	—1·27	
10 20	0·00	0·00		23	0·05	—1·04	
				31	1·18	— ·91	
10 27	0·12	2·41	Steam on.	5, 11^h 33^m	0·00	0·00	†
34	0·23	5·34					
41	0·35	6·02		11 35	0·06	2·04	Steam on.
51	0·52	6·55		54	0·36	5·12	
11 02	0·70	6·96		12 03	0·50	5·53	
33	1·22	7·50		11	0·63	5·74	
54	1·57	7·87					
12 17	1·95	8·13		12 15	0·70	5·52	Steam off.
50	2·50	8·42		24	0·85	5·01	
				35	1·03	4·74	
1 04	2·73	7·52	Steam off.	45	1·20	4·58	
15	2·92	7·21		5, 1^h 46^m	0·00	—0·00	‡
26	3·10	7·07					
42	3·37	6·97		1 52	0·10	—2·84	Steam on.
12, 1^h 49^m	.....	0·00	‡	2 03	0·28	—4·97	
2 05	0·00	0·00		08	0·37	—5·27	
				15	0·48	—5·51	
2 15	0·17	—4·04	Steam on.	24	0·63	—5·75	
20	0·25	—4·86					
30	0·42	—5·74		2 31	0·75	—5·32	Steam off.
35	0·50	—6·03		41	0·92	—4·75	
51	0·77	—6·57		51	1·08	—4·51	
3 13	1·12	—6·96		3 11	1·41	—4·33	
20	1·25	—7·20					
45	1·67	—7·53					

* τ (cold rod) — 6°, imparted before heating.
† τ (cold rod) + 6°, imparted before heating, immediately after *.
‡ τ (cold rod) — 6°, imparted before heating, immediately after †.

TABLE 45.

$T=100°$; $T'=20°$; $a=26^{cm}$; $b=30^{cm}$; $L=60^{cm}$; $k=34^{cm}$. Rods. No. 7, annealed, 360°; No. 8, annealed, 360°; $2\rho=0{\cdot}083^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 1, 10h 30m	0·00	0·00	(*)	Mar. 1, 2h 03m	0·48	−2·95	
				35	0·92	−3·22	
10 35	0·08	1·44		3 04	1·33	−3·36	Steam on.
47	0·28	1·79		24	1·73	−3·43	
59	0·48	1·91		43	2·05	−3·49	
11 12	0·70	1·99	Steam on.				
22	0·87	2·03		4 55	2·25	−2·97	
45	1·25	2·11		5 03	2·40	−2.77	Steam off.
12 00	1·50	2·15		25	2·75	−2·58	
12 15	1·75	1·52		1, 4h 40m	0·00	0·00	(‡)
57	2·45	1·20	Steam off.	4 47	0·10	1·55	
1 17	2·78	1·17		55	0·25	2·31	Steam on.
37	3·12	1·16		5 05	0·42	2·63	
1, 1h 40m	0·00	0·00	(†)	15	0·58	2·75	
47	0·12	−1·42		5 22	0·70	2·45	
51	0·18	−2·27	Steam on.	2, 9h 42m	17·03	1·65	Steam off.
58	0·30	−2·70					

* τ (cold rod) +6°, imparted before heating.
† τ (cold rod) − 6°, imparted before heating, immediately after *.
‡ τ (cold rod) + 6°, imparted before heating, immediately after †.

TABLE 46.

$\theta=100°$; $\theta'=20°$; $L=60^{cm}$; $l=30^{cm}$; $a=26^{cm}$; $\beta=34^{cm}$. Rods: No. 9, annealed, 480°; No. 10, annealed 480°; $2\rho=0{\cdot}083^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 2, 10h 53m	0·00	0·00	(*)	Mar. 3, 10h 05m	0·05	·94	
				10	0·13	1·63	
11 00	0·07	·90		15	0·21	1·85	
10	0·17	1·42		25	0·38	1·94	Steam on.
21	0·28	1·53		31	0·48	1·97	
31	0·38	1·60		43	0·68	2·00	
40	0·47	1·64	Steam on.	11 02	1·00	2·07	
58	1·05	1·68					
12 15	1·22	1·71		11 07	1·08	1·84	
55	2·02	1·44		15	1·21	1·50	
				25	1·38	1·26	Steam off.
1 00	2·07	1·55		37	1·55	1·13	
07	2·14	1·26		55	1·88	1·05	
1 24	2·31	·96	Steam off.	12 02	2·00	1·03	
34	2·41	·89		3, 12h 12m	0·00	0·00	(§)
43	2·50	·85					
2 00	3·07	·81		12 17	0·08	−1·23	
2, 2h 05m	0·00	0·00	(†)	22	0·16	−1·61	
				28	0·26	−1·45	
2 14	0·15	−1·26		33	0·35	−1·84	
19	0·23	−1·66		44	0·53	−1·92	Steam on.
24	0·31	−1·86		55	0·72	−1·97	
32	0·45	−1·99	Steam on.	1 08	0·90	−2·02	
45	0·66	−2·08		19	1·10	−2·05	
3 00	0·92	−2·15		30	1·30	−2·07	
08	1·05	−2·18		56	1·74	−2·10	
15	1·16	−2·21					
				2 00	1·80	−1·92	
3 23	1·30	−1·85		06	1·90	−1·65	
32	1·45	−1·54		12	2·00	−1·46	Steam off.
38	1·55	−1·41	Steam on.	22	2·16	−1·30	
47	1·70	−1·31		33	2·35	−1·20	
58	1·88	−1·25		49	2·61	−1·15	
4 11	2·10	−1·21					
3, 10h 02m	0·00	0·00	(‡)				

* τ (cold rod) + 6°, imparted before heating.
† τ (cold rod) − 6°, imparted before heating, immediately after *.
‡ τ (cold rod) + 6°, imparted before heating.
§ τ (cold rod) − 0°, imparted before heating, immediately after ‡.

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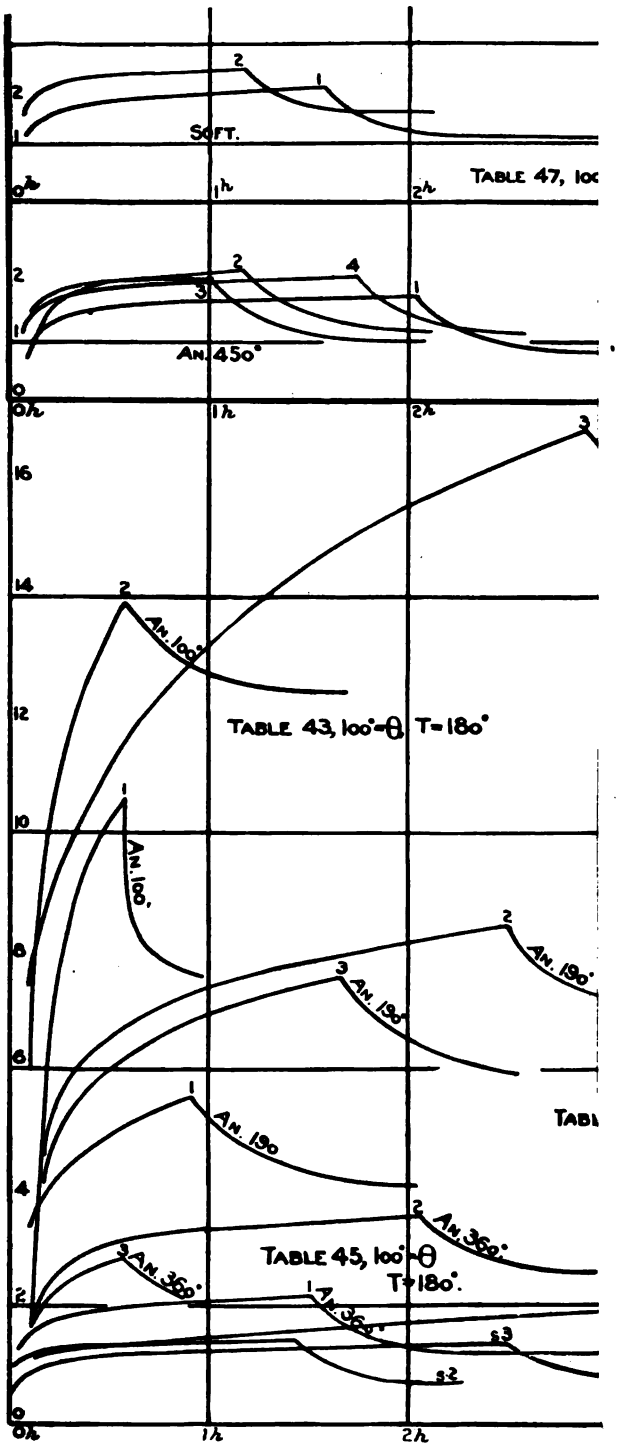


VISCOUS DEFORMATION AT 100° FOR DIFFERE

TABLE 47.

$\theta = 100°$; $\theta' = 20°$; $a = 20^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 4, 10h 08m	0·00	0·00	(*)	Mar. 4, 12h 59m	2·85	1·08	Steam off.
				1 40	3·53	1·05	
10 13	0·08	1·05		4, 1h 57m	0·00	0·00	(†)
18	0·16	1·45					
24	0·28	1·56		2 04	0·11	—1·69	
33	0·41	1·61		09	0·20	—1·63	
47	0·65	1·68	Steam on.	19	0·36	—2·11	Steam on.
57	0·83	1·73		28	0·51	—2·13	
11 12	1·06	1·79		40	0·71	—2·17	
20	1·20	1·83		3 06	1·15	—2·24	
40	1·53	1·91					
				3 10	1·21	—2·14	
11 45	1·62	1·76		16	1·31	—1·85	
11 55	1·78	1·34		24	1·45	—1·68	Steam off.
12 05	1·95	1·26	Steam off.	33	1·60	—1·58	
15	2·11	1·19		44	1·78	—1·52	
29	2·35	1·13					

* τ (cold rod) + 6°, imparted before heating.
† τ (cold rod) — 6°, imparted before heating, immediately after *.

In Pl. II I have represented the results of these Tables 42 to 47 graphically, $(\varphi-\varphi')10^3$ as a function of time. The plate therefore shows the amount of viscous deformation, at 100°, for each of the states of temper in question. The numerals in brackets indicate the number of twists applied, alternately in opposite directions. It is significant that in proportion as harder wires are operated upon, the (2) twist is in advance of the first, the third being usually intermediate as regards viscous deformation. Even in case of 190°, the oscillatory effect of counter-twisting is marked. It is obscure in soft rods. All this has an important bearing on the discussion in Chapter III, where the phenomenon of "accommodation" is discussed. It may be noted that the two parts of Table 44 are not immediately continuous; hence the difference of behavior of parts (1), (2), (3), and parts (4)′, (5)′, (6)′ of the table.

64. *Viscosity at* 190°.—The data in hand are as follows:

TABLE 48.

$\theta = 190°$; $\theta' = 20°$; $a = 20^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 5, annealed, 190°; No. 6, annealed, 190°; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_θ	$(\phi - \phi') \times 10^3$		Date.	h_θ	$(\phi - \phi') \times 10^3$	
Mar. 7, 9h 55m	0·00	0·00	(*)	Mar. 8, 9h 50m	0·25	9·81	Vapor on.
				53	0·30	10·70	
10 00	0·08	— 4·97	Vapor on.	56	0·35	11·09	
04	0·15	—14·80		10 00	0·42	12·26	
10	0·25	—12·39		08	0·56	13·52	
19	0·40	—15·81		15	0·67	14·48	
7, 12h 27m	0·00	0·00	(†)	27	0·87	15·84	
				40	1·08	17·11	
12 33	0·10	14·61	Vapor on.	47	1·20	17·89	
36	0·15	22·98		11 00	1·42	17·11	Vapor off.
40	0·22	26·83		20	1·75	16·73	
42	0·25	28·36		55	2·33	16·63	
12 55	0·47	27·01	Vapor off.	8, 12h 00m	0·00	0 00	(‖)
1 40	1·22	26·23					
7, 2h 35m	0·00	0·00	(‡)	08	0·13	— 7·23	Vapor on.
				10	0·17	— 8·34	
2 45	0·17	—11·42	Vapor on.	12	0·20	— 9·12	
47	0·20	—12·26		15	0·25	— 9·99	
53	0·30	—13·48		18	0·30	—10·71	
3 10	0·58	—15·40		21	0·35	—11·28	
19	0·73	—15·71		25	0·42	—11·95	
43	1·13	—14·28		30	0·50	—12·68	
				35	0·58	—13·34	
3 53	1·30	—16·99	Vapor off.	40	0·67	—13 85	
4 07	1·53	—16·68		45	0·75	—14·29	
45	2·17	—16·58		50	0·83	—14·69	
8, 9 00	18·42	—16·58		1 00	1·00	—15·36	
8, 9h 35m	0·00	0·00	(§)	1 12	1·20	—14·80	Vapor off.
				30	1·50	—14·49	
9 43	0·13	4·14	Vapor on.	45	1·75	—14·45	
45	0·17	6·54					
48	0·22	8·85					

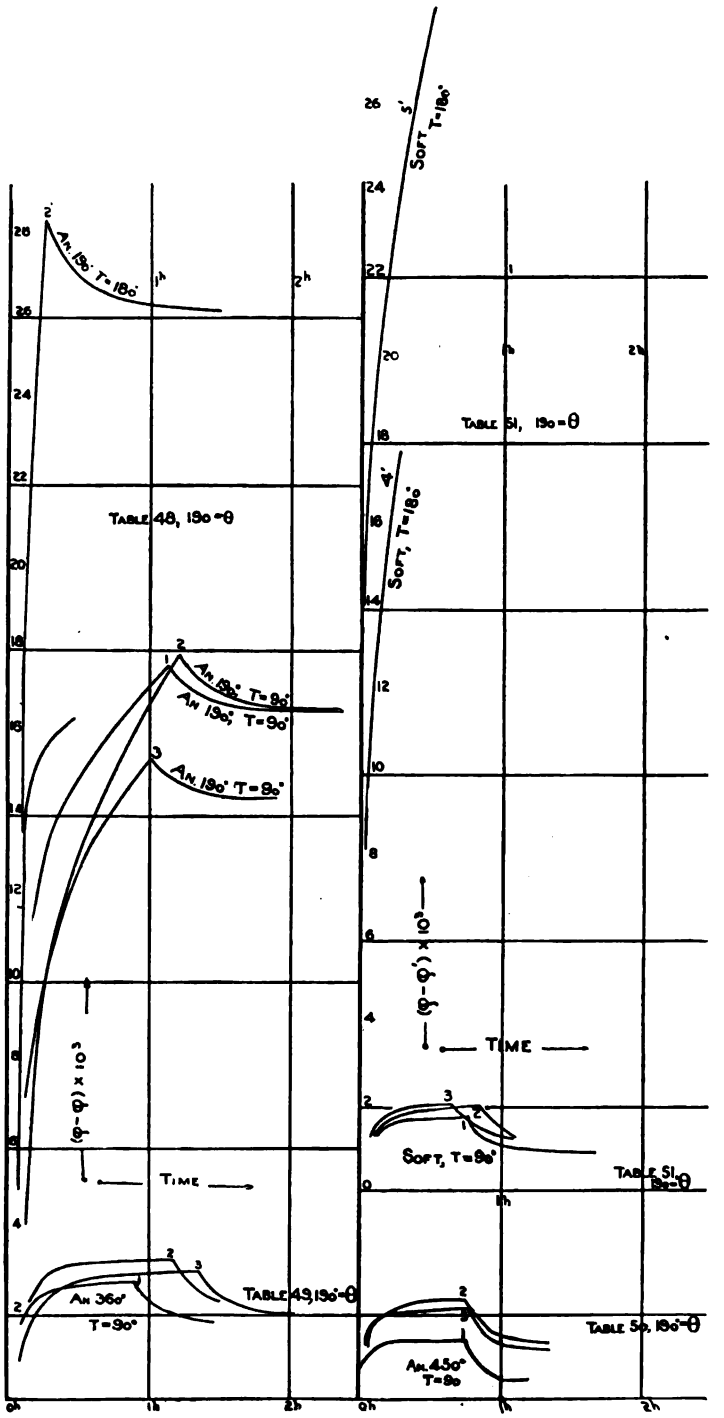
* τ (cold rod) — 6°, imparted before heating.
† τ (cold rod) + 6°, imparted before heating, immediately after *.
‡ τ (cold rod) — 3°, imparted before heating, immediately after †.
§ τ (cold rod) + 3°, imparted before heating, immediately after ‡.
‖ τ (cold rod) — 3°, imparted before heating, after §.

TABLE 49.

$\theta = 190°$; $\theta' = 20°$; $a = 20^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 7, annealed, 360°; No. 8, annealed, 360°; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_θ	$(\phi - \phi') \times 10^3$		Date.	h_θ	$(\phi - \phi') \times 10^3$	
Mar. 8, 2h 11m	0·00	0·00	(*)	Mar. 8, 5h 01m	1·33	—2.57	Vapor off.
				10	1·48	—2·34	
2 20	0·15	2·09	Vapor on.	9, 9h 27m	0·00	0·00	(‡)
25	0·23	2·47		9 32	0·08	·84	Vapor on.
36	0·42	2·63		40	0·21	2·01	
3 05	0·90	2·77		10 35	1·13	3·01	
				48	1·35	3·04	
3 12	1·02	2·26	Vapor off.				
35	1·40	1·86		11 02	1·58	2·29	Vapor off.
8, 3h 41m	0·00	0·00	(†)	07	1·66	2·19	
				17	1·83	2·09	
3 50	0·15	—2·25	Vapor on	26	1·99	2·05	
57	0·27	—2·99					
4 08	0·45	—3·21					
26	0·75	—3·25					
52	1·18	—3·32					

* τ (cold rod) + 3°, imparted before heating.
† τ (cold rod) — 3°, imparted before heating, immediately after *.
‡ τ (cold rod) + 3°, imparted before heating, immediately after †.



VISCOUS DEFORMATION AT 190° FOR DIFFERENT STATES OF TEMPER AND STRAIN.

TABLE 50.

$\theta = 190°$; $\theta' = 20°$; $a = 26^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 9, annealed, 450°; No. 10, annealed, 450°; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^1$	
Mar. 9, 11h 50m	0·00	0·00	(*)	Mar. 9, 2h 07m	0·86	1·83	Vapor off
				14	0·98	1·55	
11 55	0·08	−1·09	Vapor on.	27	1·03	1·38	
12 00	0·16	−1·29		35	1·33	1·02	
06	0·26	−1·32		9, 3h 30m	0·00	0·0	(‡)
15	0·41	−1·33		3 36	0·10	−1·83	Vapor on.
35	0·75	−1·34		40	0·17	−2·00	
12 44	0·90	− ·69	Vapor off.	47	0·28	−2·06	
51	1·01	− ·49		55	0·42	−2·07	
9, 1h 15m	0·00	0·00	(†)	4 16	0·77	−2·20	
1 21	0·10	1·78	Vapor on.	4 30	1·00	−1·33	Vapor off.
35	0·33	2·29		41	1·18	−1·14	
43	0·45	2·30		10, 9h 30m	18·00	−1·04	
2 00	0·75	2·34					

* τ (cold rod) $-3°$, imparted before heating.
† τ (cold rod) $+3°$, imparted before heating, immediately after *.
‡ τ (cold rod) $-3°$, imparted before heating, immediately after †.

TABLE 51.

$\theta = 190°$; $\theta' = 20°$; $a = 26^{cm}$; $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho = 0{\cdot}082^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 10, 10h 05m	0·00	0·00	*	Mar. 10, 1h 43m	0·00	0·00	‡
10 11	0·10	−1·16	Vapor on.	1 52	0·15	−1·75	Vapor on.
16	0·18	−1·57		57	0·23	−1·93	
23	0·30	−1·68		2 06	0·38	−2·00	
31	0·43	−1·71		15	0·53	−2·06	
40	0·58	−1·74		23	0·66	−2·08	
51	0·76	−1·78		2 29	0·76	−1·73	Vapor off.
11 11	1·10	−1·01	Vapor off.	37	0·90	−1·45	
25	1·33	− ·98		51	1·13	−1·27	
42	1·63	− ·89		10, 3h 08m	0·00	0·0	§
10, 11h 49m	0·00	0·00	†	3 20	0·20	16.2	Vapor on
12 04	0·25	1·75	Vapor on.	10, 4h 15m	0·00	0·0	‖
15	0·43	1·91		30	0·25	− ·6	
24	0·58	1·98		4 45	0·50	−30.8	Vapor on.
40	0·85	2·04					
12 45	0·93	1·73	Vapor off.				
53	1·06	1·44					
1 30	1·68	1·25					

* τ (cold rod) $-3°$, imparted before heating.
† τ (cold rod) $+3°$, imparted before heating, immediately after *.
‡ τ (cold rod) $-3°$, imparted before heating, immediately after †.
§ τ (cold rod) $+6°$, imparted before heating, immediately after ‡.
‖ τ (cold rod) $-6°$, imparted before heating, immediately after §.

The data of Tables 48 to 51 are graphically given in Pl. III. As usual three alternations of twist have been imparted in each experiment. This is indicated by numerals in parentheses, as before. In Table 48 there are two values of stored stress, of which the first ((1)′ and (2)′) is just twice as great as the other ((1), (2), (3)). The accelerating effect of doubling stress is very marked; but it is even more striking in the case of Table 51. Here the soft rod behaves like a solid toward

stress $\tau=3^\circ$ ((1), (2), (3), in Pl. II); whereas, its behavior toward stress $\tau=6^\circ$ ((4)′, (5)′), is just like a viscous fluid. This is one of the most noteworthy results of these tables. It will be specially referred to in Chapter III.

It is also to be observed that viscous oscillation does not occur in the case of soft rods (Table 51, parts (1), (2), (3)).

65. *Viscosity at* 360°.—The data in hand are as follows:

TABLE 52.

$\theta=360^\circ$; $\theta'=20^\circ$; $a=9^{cm}$; $l=30^{cm}$; $L=60^{cm}$; $\beta=34^{cm}$. Rods: No. 11, soft; No. 12, soft; $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar 11, 11h 25m	0·00	0·0	*	Mar. 11, 2h 21m	0·30	48·8	Vapor on.
11 34	0·15	— 7.8	Vapor on.	25	0·37	48·0	
36	0·18	—10·1		35	0·53	49·1	
39	0·23	—11·6		2 54	0 85	46·6	Vapor off.
44	0·32	—12 9		3 01	0·97	46·4	
47	0·37	—14·0		28	1·42	46·2	
53	0·47	—14·9		11, 4h 25m	0·00	0·0	‡
11 59	0·57	—13·1	Vapor off.	4 32	0·10	—17·4	Vapor on.
12 05	0·67	—12·4		34	0·15	—24·9	
10	0·75	—12·0		36	0·18	—28·1	
18	0·88	—11·8		39	0·23	—31·5	
27	1·03	—11·5		41	0·27	—32·7	
1 13	1·80	—11·1		45	0·33	—34·4	
11, 2h 03m	0·00	0·0	†	51	0·43	—35·6	
				57	0 53	—36·9	
2 06	0·05	7·7	Vapor on.	5 10	0·75	—38·8	
09	0·10	20·0					
11	0·13	27·7		5 17	0·87	—36·1	Vapor off.
12	0·15	35·0		26	1·02	—35·0	
15	0·20	41·7		12, 9h 25m	17·00	—33·8	
18	0·25	44·5					

* τ (cold rod) -3°, imparted before heating.
† τ (cold rod) $+3^\circ$, imparted before heating, immediately after *.
‡ τ (cold rod) -3°, imparted before heating, immediately after †.

TABLE 53.

$\theta=360^\circ$; $\theta'=20^\circ$; $a=9^{cm}$; $l=30^{cm}$; $L=60^{cm}$; $\beta=34^{cm}$. Rods: No. 9, annealed, 450°; No. 10 annealed, 450°. $2\rho=0{\cdot}082^{cm}$.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 12, 10h 04m	0·00	0·0	*	Mar. 12, 1h 10m	0·92	39·4	Vapor off.
10 10	0·10	— 4·7	Vapor on.	2 00	1·75	38·2	
31	0·45	—19·2		12, 2h 15m	0·00	0·0	‡
49	0·75	—23·1		2 19	0·06	— 9·9	Vapor on.
57	0·83	—24·8		20	0·08	—26·3	
11 15	1·18	—20·1	Vapor off.	25	0·16	—30·3	
27	1·38	—19·6		27	0·20	—33·0	
59	1·92	—19·3		28	0·22	—39·0	
12, 12h 15m	0·00	0·0	†	36	0·35	—43·3	
				47	0·63	—47·6	
12 25	0·17	28·6	Vapor on.	3 13	0·96	—44·8	
27	0·20	32·2		8 20	1·08	—42·9	Vapor off.
30	0·25	35·3		32	1·28	—42·5	
36	0·35	39·0		48	1·55		
45	0·50	42·1					
55	0·67	43·3					

* τ (cold rod) -3° imparted before heating.
† τ (cold rod) $+3^\circ$, imparted before heating, immediately after *.
‡ τ (cold rod) -3°, imparted before heating, immediately after †.

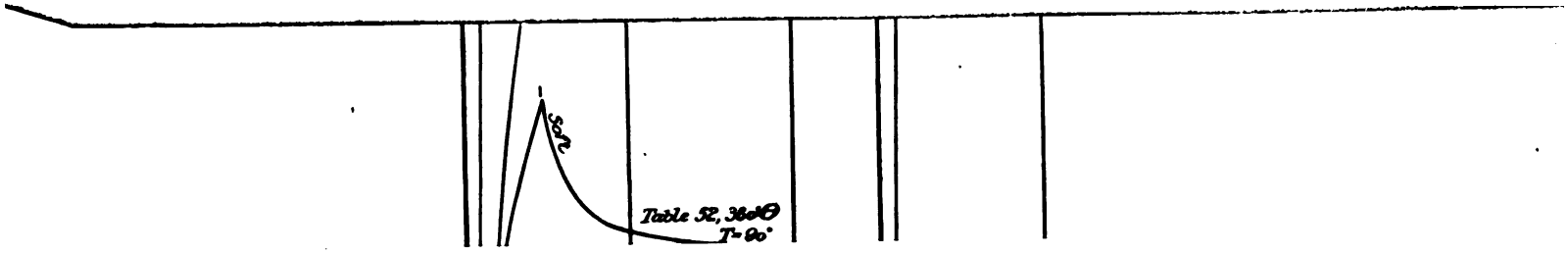

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TABLE 54.

$\theta = 360°$; $\theta' = 20°$; $a = 9^{cm}$, $l = 30^{cm}$; $L = 60^{cm}$; $\beta = 34^{cm}$. Rods: No. 7, annealed, 360°; No. 8, annealed, 360°.

Date.	h_0	$(\phi-\phi')\times 10^3$		Date.	h_0	$(\phi-\phi')\times 10^3$	
Mar. 14, 10h 00m	0·00	0·0	*	Mar. 14, 3h 19m	0·00	0·0	‡
10 03	0·07	−19·6	Vapor on.	3 22	0·05	4·6	Vapor on.
05	0·10	−26·7		23	0·07	8·9	
06	0·12	−32·0		24	0·08	14·0	
07	0·13	−36·8		25	0·10	19·3	
09	0·17	−41·3		27	0·12	26·4	
10	0·18	−44·8		28	0·15	30·1	
13	0·23	−49·5		29	0·17	34·7	
15	0·27	−51·9		32	0·22	41·1	
10 19	0·33	−51·1	Vapor off.	33	0·23	43·9	
31	0·53	−49·5		35	0·27	46·0	
40	0·68	−49·3		37	0·30	49·1	
11 04	1·08	−49·1		40	0·35	51·5	
14, 1h 32m	0·00	0·0	†	3 55	0·60	47·2	Vapor off.
1 38	0·10	16·9	Vapor on.	4 12	0·88	46·4	
40	0·13	25·2		26	1·12	46·4	
43	0·18	32·2		14, 4h 45m	0·00	0·0	§
46	0·23	37·6		4 49	0·07	− 6·4	Vapor on.
51	0·32	42·7		50	0·08	− 9·8	
59	0·45	47·0		52	0·12	−24·4	
2 02	0·50	48·9		54	0·15	−31·5	
11	0·65	51·9		56	0·18	−36·8	
2 26	0·90	47·6	Vapor off.	57	0·20	−40·2	
50	1·27	46·8		5 05	0·33	−45·0	
				5 24	0·65	−41·7	Vapor off.

* τ (cold rod) $-3°$, imparted before heating.
† τ (cold rod) $-3°$, imparted before heating, after *.
‡ τ (cold rod) $+3°$, imparted before heating, immediately after †.
§ τ (cold rod) $-3°$, imparted before heating, immediately after ‡.

In the twist (2) and (3) (Pl. IV.), the latest torsion favorable to motion stored up in the wires during the period of twist (1), asserts itself. Hence the actual stress for the former case is very decidedly greater than in twist (1). The chart again shows, that viscosity is dependent on the stress-intensity producing viscous motion, in very marked degree.

In Pl. IV the results of Tables 52, 53, 54 are graphically given, on a plan symmetrical with the above. A larger time-scale would perhaps have been preferable.

This plate preserves the character of the preceding charts. Steel annealed at 360° here shows maximum rate of viscous deformation. Indeed, the rapidity of motion for this case is extreme, so that the rod must be considered a viscous fluid. The four alternations of twist [(1), (2), (3), (4)], as before, give indications of gradually increasing viscosity; and the march toward the limit is again oscillatory.

The chart is also instructive when the behavior of steel annealed at 450° and of soft steel is considered. During twist (1) the former shows less viscosity than the latter; and both are enormously less viscous than steel annealed at 360°. But in twist (2) and twist (3) this character changes in very large degree. The reasons have already been adverted to, in considering Fig. 22 B, where stress as well as temper varies.

66. *Remarks on the tables.*—A few remarks on the tables are here in place. Large angles ψ, for the measurement of which Gauss's method is inconvenient, were calculated directly from the tangents. The error is everywhere within 1 per cent. In Table 44 and more particularly in special experiments, the observations on the constancy of the scale reading when the temperatures of both upper and lower wires are identical, prove that errors due to differences of viscosity in the cold wires are negligible. No motion is perceptible until heat has been applied. The difficulty encountered in fixing the zero of time has already been mentioned. The curves are therefore correct in their vertical dimensions, but may have been shifted laterally as much as is indicated in each table by the interval between the parts marked "vapor on" and "vapor off." It has also been stated that the results for mercury are too large because of the difficulty in accurately defining the length of the hot part *a*. Finally two sets of experiments were made with soft wire (Rods, Nos. 1, 2, 11, 12) because the viscous properties of soft wire are not sharply definable. The curves lie sometimes above, sometimes below the mean zone for steel annealed at 450°. This vagueness of the soft state is largely due to strains incidentally impressed. When a positive twist immediately follows a negative twist, or vice versa, the values of $(\varphi - \varphi')$, cæteris paribus, are larger than for the case of an untwisted wire. It is therefore to be noted that in the arrangement of apparatus employed the permanent set of any prolonged torsion is added to the following torsion, particularly in the case of high θ.

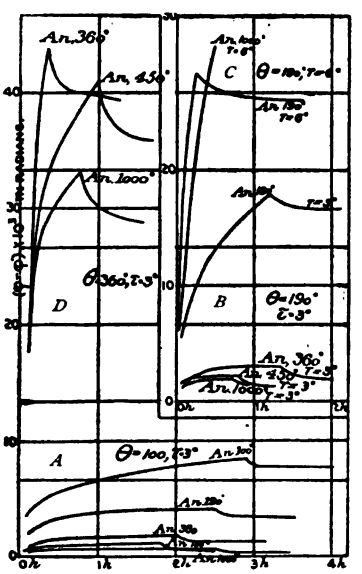

FIG. 23.—Viscous deformation increasing with time, for different states of temper and of temperature. Mean values.

DEDUCTIONS.

67. *Viscosity and temperature.*—The behavior of a given steel wire varies with the character and with the amount of twist it has received. These variations are not insignificant. Cf. Figs. 22 A, 22 B, 22 C. Hence it is expedient to construct a diagram of the mean viscous motion for each degree of hardness and then to discuss the secondary variations with reference to this diagram. In Figs. 23 A, 23 B, 23 C, 23 D $(\varphi - \varphi')$, the angular torsion in radians is exhibited as a function of time in hours, when wires in all degrees of hardness are exposed to degrees of temperature (θ) of 100°, 190° and 360° respectively. The series is made complete when the rate of twist (τ) is 3°, the values of $(\varphi - \varphi')$ corresponding to $\theta = 100°$ (Tables 42 to 47) where $\tau = 6°$ having

been divided by 2 to effect this reduction. This operation is probably not always rigorous[1]; but it is sufficiently correct for the present purposes. In the case of $\theta=190°$ experiments were made both for $\tau=3°$ (Fig. 23 B), and for $\tau=6°$ (Fig. 23 C). Each curve consists of two distinct parts, an anterior ascending branch showing the motion at the high temperature θ, and a descending branch showing the (elastic) effect of cooling from θ to room temperature (θ'). Figures 23 A to 23 D and Tables 41, and 42 to 54 clearly show that the viscous detorsion ($\varphi-\varphi'$) exhibited by steel is very much more influenced by temperature when the steel is hard than when it is soft. In other words, viscosity decreases with temperature (cæteris paribus) at much greater rates in hard steel than in soft steel. Again, at the same temperature θ, the differences of viscosity are very large when the temper of steel lies between glass-hard and annealed at 350°. Intermediate differences within this interval are larger in proportion as mean hardness is greater. When temper lies between annealed at 350° and soft, differences of viscosity at the same θ are relatively small. In general therefore the variations of viscosity due to temper are marked occurrences during the first phase[2] of annealing, and nearly vanish during the second phase, a result which corroborates the close analogy between the viscous effects of temper, the thermoelectric effect and the electric resistance effect of temper already pointed out.

68. For the same degree of hardness viscosity increases at an accelerated rate with temperature θ. In Fig. 23, where $\theta=100°$, the large viscous interval between Annealed at 100° and Annealed at 360° is in striking contrast with the smaller viscous interval Annealed at 360° to Annealed at 1000°, notwithstanding the fact that to avoid erroneous comparisons the latter interval has rather been chosen too large than too small. Indeed, the values for Annealed at 1000° in Table 47 would place the locus for soft wire even above the curve Annealed at 450° in Fig. 23, suggesting the occurrence of a maximum viscosity for $\theta=100°$. Passing from Fig. 23 to Fig. 23 B ($\theta=190°$), the interval between Annealed at 190° and Annealed at 360° is phenomenally increased. The interval Annealed at 360° to Annealed at 1000° is also increased, but only slightly. Again, passing from Fig. 23 C to 23 D ($\theta=360°$), the interval of the second phase of annealing (Annealed at 360° to Annealed at 1000°) is largely increased.[3] The marked tendency of a steel wire annealed from hardness at $\theta°$ to suffer viscous deformation when exposed to $\theta°$, is the chief result of the present paper. This tendency decreases with great rapidity in proportion as the temperature of exposure falls below θ.

[1] Cf. Weidmann: Wied. Ann., 1886, vol. 22, pp. 220, 222. He believes proportionality between stress and deformation to obtain.

[2] Am. Jour. Sci. (III), 1886, vol. 31, p. 443.

[3] Of course the degree of hardest temper to be exposed to θ for viscous comparisons is Annealed at θ. Harder wires would be annealed at this temperature and the concomitant effects due to changes of temper erroneously confounded with simple viscous motion.

As temperature increases, glass seems to lose rigidity much less rapidly than hard steel, but probably not less rapidly than soft steel. The magnetic instability of glass-hard steel is probably due to its extreme susceptibility of temperature, since every change of temper is the cause of loss of magnetic moment. This close relation between hardness and magnetism is good evidence in favor of the essentially strained character of hard steel. The full bearing of all these points is made the subject of Chapter III.

69. *Behavior of other metals.*—Kohlrausch,[1] Streintz,[2] Schmidt,[3] and Pisati[4] have discussed the effect of temperature on viscosity. More minute investigations on the relation between viscosity and temperature have recently been made with silver, platinum, iron, and german silver, and for temperatures within 100°, by Schroeder.[5] It is in place to advert in passing to certain important accordances between Schroeder's results and the present results. In the data above, one or more alternations of the sign of twist are applied to the steel wires (Tables 42 to 54, particularly Table 44), and the amount of deformation decreases (cæteris paribus) with the number of torsions applied gradually toward a limit. This fact has been studied by Wiedemann[6] and at even an earlier date though in a somewhat less relevant way, by Streintz[7] under the term "accommodation." Schroeder has apparently enlarged the importance of these observations by showing that repeated alternations of temperature from low to high values have the same effect.[8] It remains to be seen, however, whether this is not an immediate result of the fact that Schroeder's hard-drawn wires are annealed by exposure to 100°. Indeed the results of Chapter III make this altogether probable. A second result of Schroeder's,[9] viz: that the amount of "after-action," as well as the amount of change of after-action due to stated increments of temperature is greatest in silver, of intermediate value in iron, and smallest in german silver, has an important bearing on the present experiments. The present results taken together with the earlier paper of Barus and Strouhal[10] show conclusively that the viscosity of steel and the variation of viscosity due to temperature increase in like order, and in ways which throughout the course of the phenomena are thoroughly analogous. A final result of Schroeder's bearing on the present paper, viz: that the viscous detorsion occurring at 100° is arrested by suddenly lowering the temperature

[1] Kohlrausch: Pogg. Ann., 1866, vol. 128, p. 216; 1876, vol. 158, p. 371.
[2] Streintz: Wien. Berichte, 1874, vol. 69, p. 337.
[3] Schmidt: Wied. Ann., 1877, vol. 2, p. 264.
[4] Pisati: Wien. Berichte, 1879, vol. 80, p. 427.
[5] Schroeder: Wied. Ann., 1886, vol. 28, p. 369.
[6] Wiedemann: Wied. Ann., 1879, vol. 6, p. 512.
[7] Streintz: Pogg. Ann., 1874, vol. 153, p. 406.
[8] "Ebenso wie das log. Decrement bei Torsionschwingungen zeigt auch die Nachwirkung unter dem Einflusse wiederholter Temperaturänderungen eine Accommodation."
[9] "Sowohl die Nachwirkung wie die Änderung derselben mit der Temperatur ist am grössten beim Silberdraht, geringer beim Eisen, am kleinsten beim Neusilberdraht."
[10] *Am. Jour. Sci. (III), 1887*, vol. 33, pp. 25, 26.

as far as 20° is again fully corroborated by the behavior of steel; but the character of the viscous motion while the temperature either rises or falls does not so fully appear, because a large part of the retrograde movement observed during cooling is here to be ascribed to concomitant changes of the modulus of elasticity produced by temperature. In other words, relatively large variations of elasticity are superposed upon and obscure the nature of the viscous detorsion during the interval of transition from high to low temperature, or from low to high temperature.

70. It is because of the mixed character of the retrograde movement that I refrain from using the data for the construction of the temperature relations of the rigidity of steel. If a device for cooling with sufficient rapidity to annul the viscous movement be applied, then the present method may be used at once for investigating the effect of temperature on rigidity.

71. *Viscosity and pressure.*—In view of the great importance of viscous deformations in questions of dynamic geology, I will insert a few remarks relative to the effect of pressure on viscosity, such as follow at once from the above experiments.

At a depth of ten miles below the surface, the temperature of the stratum of earth is certainly as high as 450° C.[1] At this temperature glass is practically a viscous fluid as appears at once from experiments by Dr. Strouhal and myself, on the strain effect of quenching exhibited by the Prince Rupert drop.[2] We found all strain to have vanished when the temperature of annealing reached this limit. Special experiments on the torsion viscosity of glass made with the above apparatus shows a similarly marked effect at 370°, so that glass which is less viscous than soft steel at mean atmospheric temperatures maintains this state of inferiority when temperature is raised. It is not necessary to tabulate the experiments with glass here. They are difficult of reduction, because glass-fiber can not easily be drawn to have the same uniform section throughout its length. Again, at these temperatures glass easily devitrifies, a phenomenon which decreases its viscosity enormously. The omission is easily justified since Warburg and others have proved that even at 300° glass behaves like an electrolyte (cf. Chapter I).

It follows that if the earth were of glass, and if the viscous effect of pressure were nil, the behavior of strata at even ten miles below the surface would be that of a viscous fluid. Indeed the strata there and to some extent above this level, would yield to the application of even small intensities of shear.

Again, if the earth were made of steel in the state of maximum viscosity, the rigidity ten miles below the surface would be nil, so far at least as the action of *continuous* shearing stress is concerned.[3]

[1] Cf. Thomson and Tait Nat. Philosophy, I, part 2, 1883, pp. 476 to 477.

[2] Bull. U. S. Geol. Survey, No. 42, 1888, p. 109.

[3] Considerations *of this kind* have been made specifically and carried out in detail by Mr. Clarence King.

It follows finally that, if the earth, throughout depths of this insignificant value, behaves like an elastic solid, the effect of pressure on viscosity must be of importance.

72. *Sudden and gradual deformation.*—In the experiments for $\theta=100^{\circ}$ the rate of twist $\tau=6^{\circ}$ was uniformly applied. The results were then approximately reduced to $\tau=3^{\circ}$ by merely halving the values of $(\varphi-\varphi')$. Pl. III shows that the same strain, $\tau=6^{\circ}$, applied for $\theta=190^{\circ}$, is too large for convenient measurement by Gauss's method. On applying $\tau=3^{\circ}$ directly, the completed series of results is obtained. Comparing the loci of Pl. III and Fig. 23 C, it appears clearly that $(\varphi-\varphi')$ increases very much more rapidly than τ. Moreover, if the rate of increase of τ be 2, the rate of increase of $(\varphi-\varphi')$ is certainly as much as 3 in case of steel annealed at 190°, and even more than 10 in case of soft steel (annealed at 1000°). It follows therefore very probably that the viscous relations of soft steel to hard steel vary enormously and even change sign as the stress producing viscous motion passes from low to high values. This is an important deduction. For rates of twist less than $\tau=3^{\circ}$ for the diameter $2\rho=0{\cdot}082^{cm}$, steel is less viscous, and as regards viscosity much more susceptible to the influence of temperature, in proportion as it is harder. For rates of twist greater than $\tau=6^{\circ}$ steel is less viscous and more susceptible to the influence of temperature in proportion as it is softer.[1] The complete coördination of these facts, in other words the full expression of the viscosity of steel as a function of hardness for all degrees of temperature θ and all values of stress τ, will be the key for the explanation of the mechanical behavior of steel and its important bearing on magnetic, electrical and other properties of the metal. To elucidate these remarks I will complete the description of the apparatus with which the present results were obtained, leaving theoretical inferences for discussion in Chapter III.

73. In the apparatus, Pl. I, suppose the lower (cold) wire to be in connection with clockwork, in such a way that it may be twisted uniformly, at any given velocity, variable at pleasure. Suppose the method of adjusting the index to be such as is suitable for the measurement of angles of any magnitude. If the clock be set in motion from $\tau=0$, the strain will increase at some determinate arbitrary rate. For a given value of θ, therefore, a family of curves may be obtained in which the angular motion of the index ψ_1 for a given wire must be expressible as a function of the time during which twisting has taken place and the rate at which the strain is increased. In other words, if c be the rate of rotation of the lower end of the lower wire, the experimental results may be symbolized by

$$\psi_1 = f_1(t, c_1)$$
$$\psi_2 = f_2(t, c_2)$$
$$\psi_n = f_n(t, c_n),$$

[1] Cf. Carus Wilson: Phil. Mag., 1890, vol. 29, p. 200.

where t is the symbol of time. It follows that the strain per centimeter of the total length L, at any time t, will be ct/L diminished by the amount of viscous motion.[1] Hence it is experimentally possible and fully feasible to pass from the family of curves $\psi_1, \psi_2, \ldots \psi_n$ to a similar family,

$$(\varphi - \varphi') = F(t, \tau),$$

by an appropriate method of graphic solution. $(\varphi - \varphi')$ thus expressed as a function of time and strain, for all degrees of hardness and all degrees of temperature θ, is the complete solution of the problem in hand.

I take pleasure in acknowledging that the greater number of experiments in this paper are due to Mrs. Anna H. Barus.

[1] If c' be the rate of the index for perfectly elastic wires, then $\psi - c't$, and $2c't - \psi$ correspond respectively to the viscous motion and the strain intensity at the time t. The curves ψ will in general be circumflex, passing from an initial tangent c' to an asymptote which is the rate of rotation of the lower end of the wires.

CHAPTER III.

MAXWELL'S THEORY OF THE VISCOSITY OF SOLIDS AND ITS PHYSICAL VERIFICATION.

INTRODUCTION.

74. The viscosity of solids has been theoretically discussed in the memoirs of O. E. Meyer, Boltzmann, Neesen, Warburg, Maxwell, and Butcher. Views of a distinctly theoretical kind have also been given by Weber and Kohlrausch, and more recently by Nissen. In almost all cases, excepting alone Butcher's[1] work, which formulates the theory of Maxwell,[2] the problem has been approached from distinct points of view.

Despite the diversity of methods of discussion and the elaboration of evidence, the results do not in any case so fully represent the phenomenon as to lead to general acquiescence in one elementary physical hypothesis. Boltzmann's theory is perhaps the most powerful and is elegantly worked out; but it is purely mathematical in character. Maxwell's theory has the broadest physical basis, although left by its author in shape merely of a terse verbal sketch.

Now it seems to me, if indeed I may venture any assertion, that Maxwell's theory is a version of Williamson's[3] theory of etherification, and of Clausius's[4] theory of electrolysis. The transition made is from unstable groupings of atoms to unstable groupings of molecules. But preserving minutely all the essentials of Maxwell's argument, the experiments of this paper justify the assumption that viscosity is a phenomenon evoked by certain changes of molecular structure, the inherent nature of which is ultimately chemical. I say chemical because if molecular break up occur, cardinal questions at once arise as to the manner of removal of the debris; and the phenomenon thus depends not only on the past history, but on the immediate future history of the typical mean configuration. The analogy of the three theories is very close, so that they admit of generic classification. They are examples of the invasion of statistical method into liquid and solid molecular kinetics.

The behavior of steel when regarded as a viscous solid and in the light of known facts,[5] is convincingly in favor of the view to be advocated;

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[1] Butcher: Proc. Lond. Math. Soc., 1878, vol. 3.

[2] Maxwell: "Constitution of Bodies," Ency. Brit., 9th ed., 1876, vol. 6, p. 310.

[3] Williamson: Ann. d. Chem. u. Pharm., 1851, vol. 77, p. 37.

[4] Clausius: Pogg. Ann., 1857, vol. 100, p. 353; ibid., 1857, vol. 101, p. 338.

[5] I refer in particular to the work of Dr. Strouhal and myself. These papers, systematically discussed and enlarged, are embodied with much new matter in the bulletins of the U. S. Geological Survey, viz: Bull. No. 14, 1885, pp. 1–226; Bull. No 27, 1886, pp. 30, 61; Bull. No. 35, 1886, pp. 11–60; Bull. No. 42, 1887, pp. 98–131. Other references are given in the text.

and it was the direct bearing of some of the results on Clausius's theory of electrolysis, that led me to suspect a chemical explanation,[1] before I became aware of the existence of Maxwell's article. To show how clearly Maxwell's theory interprets the complex and almost anomalous phenomena of viscosity exhibited by steel, is the chief endeavor of the present paper; but I shall also add other matter.

HISTORICAL SKETCH OF THE THEORIES OF SOLID VISCOSITY.

75. It is desirable to pass in brief review the divers hypotheses on the nature of solid viscosity to which I have referred.

O. E. Meyer's[2] *theory* is the earliest and most direct. It discusses the action of elastic forces in a medium of imperfect elasticity, and develops formulæ to express the diminution of stress in virtue of the occurrence of internal friction.[3] The results to which Meyer's formula eventually leads are incomplete and were not fully verified by subsequent experiment. The theory is therefore sharply antagonized by Boltzmann,[4] by Streintz,[5] and by Kohlrausch.[6] In later paper Meyer[7] partially assents to these adverse views, acknowledging that the theory does not reproduce the phenomenon actually observed. It also fails, as Kohlrausch (loc. cit.) pointed out, in predicting an insufficiently slow time of occurrence. After giving reasons for dissenting from Boltzmann's and from Neesen's hypotheses, Meyer proceeds to partially develop an older idea of Weber's.[8] This physicist referred viscosity in solids, to partial molecular rotation, a view adopted by Kohlrausch,[9] by whom it has been more clearly interpreted. The rotations underlying Weber's phenomenon are considered identical with the rotations of molecule postulated by Clausius[10] in discussing shear. Following Meyer and others, "elastische Nachwirkung" is a possible occurrence in liquids.

76. *Boltzmann's*[11] *theory*, amplifying deductions of Lamy and of Clebsch, is based on the assumption that the elastic forces are dependent not only on the present but on the preceding deformations of the body. The effect of earlier states of stress on the existing stress diminishes with the intervening time but is independent of intervening states of

[1] Am. Jour. Sci. (III), 1887, vol. 33, p. 28. It is much to be regretted that Maxwell's theory was published out of the line of a physicist's usual routine reading.

[2] Meyer: Pogg. Ann., 1874, vol. 151, p. 108.

[3] Following the usage of the term by Navier, Cauchy, Poisson, St. Venant, Stokes, Stefan. Cf. Meyer, loc. cit.

[4] Boltzmann: Pogg. Ann., Ergänzb., 1876, vol. 7, p. 624.

[5] Streintz: Pogg. Ann., 1875, vol. 155, p. 588; ibid., 1874, vol. 153, p. 405.

[6] Kohlrausch: Pogg. Ann., 1877, vol. 160, p. 225.

[7] Meyer: Wied. Ann., 1878, vol. 4, p. 249.

[8] Weber: Pogg. Ann., 1835, vol. 34, p. 247; ibid., 1841, vol. 54, p. 1.

[9] Kohlrausch: Pogg. Ann., 1866, vol. 128, p. 413; cf. also ibid., 1863, vol. 119, p. 337.

[10] "Wenn ein solcher Körper fremden Kräften unterworfen wird, die von verschiedenen Seiten ungleich auf ihn wirken, also z. B. nach einer Dimension gedehnt wird, während er nach anderen Dimensionen frei bleibt oder gar zusammengedrückt wird, dann die Moleküle neben ihrer Verschiebung sich auch etwas drehen können, indem sie in Bezug auf ihre Kraftrichtung den ungleichen Spannungen etwas folgen. . . . " Pogg. Ann., 1849, vol. 76, p. 66.

[11] Boltzmann: Pogg. Ann., Ergänzb., 1876, vol. 7, p. 624.

stress. Different viscous deformations are superposable. Boltzmann's theory, therefore, presupposes the phenomenon[1] and brings the laws of viscosity tersely into formulæ. If ω is an interval of time reckoned back from $t-\omega$, when the strain $\theta_{t-\omega}$ existed, then Boltzmann's law may be clearly exhibited in its application to the problem of vibration of a viscous solid. Given a wire of the solid of length l and radius R. Let the upper end be fixed, and the lower end be attached to a heavy bob, whose moment of inertia for the given conditions is K. Then the equation of motion is (slow oscillation presupposed)

$$D-K\frac{d^2\theta_t}{dt^2}=\frac{\pi R^4}{2l}\left\{\mu\theta_t\int_0^\infty\psi(\omega)\theta_{t-\omega}d\omega\right\},$$

where D is the moment of the applied couple, μ Lamy's constant, and ψ some function of ω. Replying to Meyer's critique that a theory of this kind is at variance with the present state of knowledge in atomistics, Boltzmann[2] disclaims all present purpose to connect his theory with definite physical hypotheses. He points out, however, that the assumed dependence of the existing strain on foregoing deformations is easily justified when the simultaneous changes of molecular configuration are taken into account; for it is not necessary to suppose that the elastic forces *as such* have any dependence on the preexisting stress. The changes of configuration in question are closely similar to Maxwell's, so that in this respect Boltzmann's theory may be looked upon as one form of mathematical development of Maxwell's physical hypothesis. I may add that Boltzmann tested his theory with data of Kohlrausch, Neesen, and Streintz. A special series of experiments subsequently undertaken by Kohlrausch[3] give additional strength to Boltzmann's deductions. The theory does not, however, predict permanent set.

77. *Neesen's theory.*—A theory similar to Boltzmann's, but atomistic in character, is due to Neesen.[4] It also assumes the occurrence of solid viscosity. Neesen distinguishes the forces producing and retarding motion and the final purely elastic forces which obtain when viscous motion has subsided. Neesen practically postulates a change in the constants of elasticity. Warburg[5] objects to Neesen's deductions because they contain no reference to the form of the molecule. Meyer (loc. cit.) fails to find in it definite causal relations to the observed viscous motion.

Braun's[6] research, though largely experimental in character, deserves mention here, because of special light which it throws on the superposition of different viscous deformations. Excepting in glass,[7] he finds

[1] Kohlrausch: Pogg. Ann., 1877, vol. 160, p. 227.
[2] Boltzmann: Wied. Ann., 1878, vol. 5, p. 430.
[3] Kohlrausch: Pogg. Ann., 1877, vol. 160, p. 225.
[4] Neeson: Pogg. Ann., vol. 1876, 157, p. 579.
[5] Warburg: Wied. Ann., 1878, vol. 4, p. 233.
[6] Braun: Pogg. Ann., 1876, vol. 159, p. 337; cf. Kohlrausch: Pogg. Ann., 1877, vol. 160, p. 227.
[7] *I do not* believe that glass is an exception. The occurrence of devitrification, for instance, decreases *the viscosity of glass enormously*, as I found. Other points of view will be adduced in another paper.

that these molecular motions do not take place independently of each other. He concludes that elastic and viscous deformations owe their occurrence to forces of different origin, and he refers viscous motion to the partial rotations postulated by Weber and Kohlrausch.

Warburg's theory.—Warburg,[1] following out the suggestions contained in Braun's results, formulates a new theory, in which viscosity is the result of partial rotations of molecules of a form other than spherical.

78. *Nissen's*[2] *theory* is unique. He considers the ether in the space surrounding the body, in its relations to the ether within the intermolecular spaces of the body; and he bases his theory on the conditions under which the external ether enters the said intermolecular spaces when the body is deformed by stress. He thus obtains both a time and a thermal effect. In many respects this curious theory seems to anticipate Osborne Reynolds[3] in recognizing the importance of the "dilitancy" of a granular medium.

79. *Maxwell's*[4] *theory* would require more extended comment; but the

[1] Warburg: Wied. Ann., 1878 vol. 4, p. 232.

[2] Nissen: Inaug. Dissert., Bonn. 1880. (Not accessible to me.)

[3] Reynolds: Phil. Mag., V, 1885, vol. 20, p. 469.

[4] Maxwell: Encyclop. Brit., 9th ed., 1876, vol. 6, p. 311.

The theory is here subjoined in full:

The molecules of all bodies are in motion. In gases and liquids the motion is such that there is nothing to prevent any molecule from passing from any part of the mass to any other part; but in solids we must suppose that some, at least, of the molecules merely oscillate about a certain mean position, so that, if we consider a certain group of molecules, its configuration is never very different from a certain stable configuration about which it oscillates.

This will be the case even when the solid is in a state of strain, provided the amplitude of the oscillations does not exceed a certain limit, but if it exceeds this limit the group does not tend to return to its former configuration, but begins to oscillate about a new configuration of stability, the strain in which is either zero, or at least less than in the original configuration.

The condition of this breaking up of a configuration must depend partly on the amplitude of the oscillations, and partly on the amount of strain in the original configuration; and we may suppose that different groups of molecules even in a homogeneous solid are not in similar circumstances in this respect.

Thus we may suppose that in a certain number of groups the ordinary agitation of the molecules is liable to accumulate so much that every now and then the configuration of one of the groups breaks up, and this whether it is in a state of strain or not. We may even in this case assume that in every second a certain proportion of these groups break up, and assume configurations corresponding to a strain uniform in all directions.

If all the groups were of this kind, the medium would be a viscous fluid.

But we may suppose that there are other groups the configuration of which is so stable that they will not break up under the ordinary agitation of the molecules unless the average strain exceed a certain limit, and this limit may be different for different systems of these groups.

Now if such groups of greater stability are disseminated through the substance in such abundance as to build up a solid framework, the substance will be a solid, which will not be permanently deformed except by a stress greater than a certain given stress.

But if the solid also contains groups of smaller stability and also groups of the first kind which break up of themselves, then when a strain is applied the resistence to it will gradually diminish as the groups of the first kind break up, and this will go on till the stress is reduced to that due to the more permanent groups. If the body is now left to itself, it will not at once return to its original form but will do so only when the groups of the first kind have broken up so often as to get back to their original state of strain.

This view of the constitution of a solid, as consisting of groups of molecules some of which are in different circumstances from others, also helps to explain the state of the solid after a permanent deformation has been given to it. In this case some of the less stable groups have broken up and assumed new configurations, but it is quite possible that others, more stable, may still retain their original configuration, so that the form of the body is determined by the equilibrium between these two set of groups; but if, on account of rise of temperature, increase of moisture, violent vibration, or any other cause, the breaking up of the less stable groups is facilitated, the more stable groups may again assert their *sway, and tend to restore* the body to the shape it had before its deformation.

terms in which his views are expressed are so precise, that it is impossible to abbreviate them. cf. §99. Aside from the remarks of the next paragraph, the ideas underlying Maxwell's theory have been given by many others, indeed by almost all the chief writers on solid viscosity; but Maxwell carries them through consistently to a complete theory.

I have stated that Maxwell's theory is the analogue of Clausius's theory of electrolysis. Where the latter uses "Theil molecüle" and electromotive force to effect chemical decomposition, Maxwell has unstable configurations and stress available to produce permanent deformation. In Clausius's case the number of decomposable molecules (i. e. unstable configurations as regards the action of electromotive force), in any given case of actual electrolysis, is practically infinite. This corresponds to Maxwell's viscous fluid, hard or soft. In a viscous solid, molecular configurations are present in all degrees of stability, with a sufficient preponderance of stable configuration to constitute a solid framework. The relative number of unstable configurations varies with the viscosity of the material. If, therefore, I conceive the case of an electrolyte exhausting itself with respect to electrical conductivity, by the chemical decomposition induced by current, until conduction cease, I have the analogue of a solid which is reaching the limit of viscous deformation. cf. §107.

80. From this analogy it follows that a solid (?) electrolyte is necessarily viscous; whereas a viscous solid is only an electrolyte when the molecules break up into parts oppositely charged. Again, a viscous solid (?) is probably more viscous when undergoing electrolytic decomposition than when no current passes through it.[1] Experiments to the same effect can, however, be made with greater facility, if the solid operated on is such that *special* instability of molecular configuration is superinduced by heat, instead of electrical action. Such a solid is hard steel, in which, in addition to the ordinary thermal instability, what may be called a *carburation instability* of molecular configuration asserts itself, even at mean atmospheric temperatures, and in the homogeneous metal. Inasmuch therefore as the gist of Maxwell's theory is instability of configuration, it follows that the evidence which can be derived with reference to it, from hard steel, must be unique in character: for despite the extreme hardness and elasticity of tempered steel, instability of molecular configuration *demonstrably* exists,[2] and is distributed uniformly throughout the metal; moreover the number of unstable groups can be made to vary over an enormous range, at pleasure.

I must distinctly state, however, at the outset, that Maxwell limits his considerations to configurations of molecules. The responsibility of fusing Clausius's and Maxwell's theories rests with me. The step is

[1] I have since been at some pains to verify this surmise, working with glass at 360°. But the experiments thus far are not decisive, because the amount of current passing through glass is not only very small, but soon ceases entirely even in the case of thin-walled tubes (Warburg, Wied. Ann., vol. 21, p. 622). On the other hand, if the current passes the electrolyte in strict accordance with Ohms law, it will produce no *special* decomposition, and will not therefore affect the viscosity of the solid *electrolyte*.

[2] *Barus and Strouhal*: Am. Jour. Sci. (III) vol. 32, 1886, p. 276.

dictated by the behavior of steel, in which the integrity of the molecule is certainly invaded without producing essential differences in the character or history of the viscous phenomena (§ 98). I may note that the occurrence of chemical change makes the hypothesis verifiable.

EXPERIMENTAL RESULTS.

APPARATUS.

81. The remarks made in the preceding sections clearly show, that notwithstanding the abundance of experimental data in hand, further researches tending to throw light on the ultimate nature of viscosity are urgently called for. To obtain such I made a new set of experiments on the plan indicated in Chapter II, modifying the apparatus there described in the following respects. The lower wire of the system is provided with a torsion circle of large radius, by aid of which the amount of permanent set of the wires can be accurately registered. In this way also any amount of twist can be permanently stored, at the operator's pleasure. Again the basin X in Pl. I was replaced by a ring-shaped basin surrounding the wires so that the wire could be twisted without removing the vane. In other respects the present experiments are like the above, except that the individual viscous detorsions were not watched for so long a period as occurs in Chapter II.

82. *Theory of the apparatus.*—This has been fully given in Chapter II, §§ 56 to 59.

83. *Measurements with steel.*—The following tables exhibit the new results for steel. About twenty rods were examined. Table 55, after enumerating the rod ("No."), and stating the temperature at which it was annealed (abbreviated "An.") from glasshardness, gives the amount of twist, τ (radians), temporarily imparted per unit of length, and $2(\varphi+\varphi')$, the mean amount of viscous detorsion, in radians per unit of length, observed immediately after the end of the experiment. $2(\varphi+\varphi')$ is therefore the mean viscous effect of τ impressed on the system of two vertical wires. Hence $\tau+2(\varphi+\varphi')=2\pi/L$. Furthermore, θ' is the temperature of the lower wire, θ that of the upper wire, and $(\varphi-\varphi')/\tau$ (radians) is the amount of viscous detorsion, as observed at the index between the wires, at the time specified, per unit of τ. Regarding this differential quantity, which is the chief datum of the tables, it is merely necessary to call to mind that 2φ is the viscous detorsion, per unit of length of the upper wire, for the rate of twist τ; and $2\varphi'$ has the same signification relatively to the lower (normal) wire. The reference to the unit of τ is a convenience permissible when τ, as in the present work, has nearly the same value throughout.[1]

The normal wire, No. 7, with which all the other steel wires are compared, is annealed from hardness at 450°, and has been twisted back

[1] In how far such reductions are generally permissible, cf. Weidmann: Wied. Ann., 1886, vol. 19, pp. 220, 222.

and forth till viscosity is practically unchanged by further twisting within the same limits. It is therefore in a state of extreme viscosity, and at the same time less liable to permanent set than a soft steel wire. Its dimensions are $l'=30^{cm}$, radius $=\rho=0{\cdot}0405^{cm}$, so that $l'=l$. The wire of unknown viscosity is examined at 20° (nearly), and immediately after at 100°. Two experiments are made at each temperature with τ alternately positive and negative. When τ and $(\varphi-\varphi')/\tau$ have the same signs (the usual case), the lower wire, No. 1, is of greater viscosity. In case of $\theta=100°$, only a part of the upper wire, length $a=\alpha-\beta$, could be heated; the remainder being kept at the lower temperature θ'. Time is conveniently given in minutes, reckoned after twisting.

84. *Viscous behavior of the rods.*—This is given in the following table:

TABLE 55.—VISCOUS DETORSIONS OF HARD STEEL.

$l=30^{cm}$. $\rho=0{\cdot}0405^{cm}$. $a=28{\cdot}5^{cm}$. $\beta=31{\cdot}5^{cm}$.

No. An.	$\frac{\tau}{2(\phi+\phi')}$	$\frac{\theta}{\theta'}$	Time.	$\frac{\phi-\phi'}{\tau}\times10^3$	No. An.	$\frac{\tau}{2(\phi+\phi')}$	$\frac{\theta}{\theta'}$	Time.	$\frac{\phi-\phi'}{\tau}\times10^3$
2	−·1045	20	3	+0·00	2	−·1027	100	2	− 0·00
450°		20	17	·03	450°		20	6	− ·92
			50	·05				18	− 1·97
	−·0003		60	·06				20	− 2·49
								45	− 3·08
						−·0020		58	− 3·47
	+·1027	20	1	−0·00		+·1027	100	2	+ 0·00
		20	8	− ·06			20	20	1·71
			28	− ·12				33	2·56
	+·0020		52	− ·12		+·0020		47	3·21
3	−·1033	20	2	+0·00	3	−·1027	100	2	− 0·00
450°		20	6	·17	450°		20	11	− ·88
			19	·34				20	− 1·21
			28	·43				34	− 1·51
	−·0014		44	·49		−·0020		48	− 1·97
	+·1030		2	−0·00		+·1027	100	2	+ 0·00
			8	− ·03			20	10	3·11
			20	− ·03				18	4.65
	+·0017		30	− ·03		+·0020		24	5·50
4	−·1033	22	2	−0·00	4	−·1007	100	3	− 0·00
360°		22	17	− ·19	360°		22	15	− 1·74
			42	− ·24				28	− 2·48
	−·0014		54	− ·24		−·0041		46	− 3·05
	+·1007	22	1	+0·00		+·0998	100	2	+ 0·00
		22	33	1·47			22	12	5·32
			44	1·61				22	7·62
	+·0041		64	1·77				37	9·86
						+·0049		49	11.07
5	−·1027	23	2	−0·00	5	−·1019	100	3	− 0·00
360°		23	15	− ·19	360°		23	22	− 2·24
			21	− ·25				32	− 2·94
	−·0020		34	− ·28		−·0029			
	+·1021	23	2	+0·00		+·1015	100	2	+ 0·00
		23	12	·25			23	7	2·12
			19	·29				20	4·04
	+·0026		27	·31		+·0032		27	4·74
6	−·1035	19	2	−0·00	6	−·1023	100	1	− 0·00
190°		19	5	− ·12	190°		19	4	− 3·69
			17	− ·28				12	− 8·02
			35	− ·18				20	−10·39
								29	−12·95
	−·0012					−·0024		36	−13·35
	+·1035	19	2	+0·00		+·1003	100	1	+ 0·00
		19	19	·00			19	5	8·18
			31	·06				10	13·29
								15	16·98
								20	19·53
								26	22·14
								32	24·10
	+·0012					+·0044		38	25·87

TABLE 55.—Continued.

$l = 30^{cm}$. $\rho = 0{\cdot}0405^{cm}$. $a = 28{\cdot}5^{cm}$. $\beta = 31{\cdot}5^{cm}$.

No. An.	$\frac{\tau}{2(\phi+\phi')}$	$\frac{\theta}{\theta'}$	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$	No. An.	$\frac{\tau}{2(\phi+\phi')}$	$\frac{\theta}{\theta'}$	Time.	$\frac{\phi-\phi'}{\tau}\times 10^3$
7	−·1027	20	2	− 0·00	7	−·1007	100	1	− 0·00
190°		20	8	− ·64	190°		20	3	− 3·88
	−·0020		18	− 1·02				8	−11·10
								19	−19·47
								33	−25·02
						−·0041		40	−26·95
	+·1009	20	1	+ 0·00		+·1003	100	2	+ 0·00
		20	9	1·17			20	9	10·81
			20	1·77				16	16·03
			30	2·08				26	20·67
	+·0038		50	2·58		+·0044		40	24·75
8	−·1035	20	2	− 0·00	8	−·1007	100	3	− 0·00
190°		20	12	− ·24	190°		19	11	− 9·02
			19	− ·37				20	−14·51
	−·0012		27	− ·37				32	−18·67
						−·0041		55	−23·88
	+·1030	20	2	+ 0·00		+·0995	100	2	+ 0·00
		20	9	·43			19	11	17·05
			17	·71				22	26·59
			33	·99				28	29·30
	+.0017		44	1·15		+·0052		41	34·59
9	−·1033	19	2	− 0·00	9	——	100	2	− 0·00
100°		19	8	− ·55	100°	——	19	5	−17·50
	−·0014		27	− 1·48				8	−26·93
	+·1023	19	3	+ 0·00		Accident.			
		19	10	1·03					
			31	2·33					
	+·0023		42	2·74					
10	−·1041	20	1	− 0·00	10	−·0974	100	1	− 0·00
100°		20	12	− ·92	100°		20	3	−20·38
			25	− 1·34				7	−32·33
	−·0006		38	− 1·65				16	−56·23
								19	−62·31
						+·0073		21	−65·63
	+·1023	20	2	+ 0·00		+·0968	100	2	+ 0·00
		20	21	1·74			20	5	15·08
	+·0022		45	2·48				8	24·41
								12	33·30
								18	42·96
								22	48·14
								25	51·79
								32	59·43
								35	61·23
						+·0078		42	67·76
11	−·1033	21	1	− 0·00	11	+.1007	100	2	− 0·00
100°		21	8	− ·46	100°		20	5	− 8·56
			32	− ·80				10	−16·18
	−·0014		48	− ·89				16	−22 06
								22	−26·49
						−·0041		26	−29·03
	+·1027	21	2	+ 0·00		+·0966	100	3	+ 0·00
		21	12	1·18			20	5	5·79
			26	1·82				16	30·88
			37	2·17				23	40 79
	+·0020		50	2·46				31	49·84
								37	55·57
						+·0081		45	62·39

TABLE 55—Continued.

$l=30^{cm}$. $\rho=0{\cdot}0405^{cm}$. $a=28.5^{cm}$. $\beta=31{\cdot}5^{cm}$.

No. An.	τ $2(\phi+\phi')$	θ θ'	Time.	$\frac{\phi-\phi'}{\tau}\times10^3$
12 25°	+·1007	22 22	2 5 11 29 36	+ 0·00 2·28 4·24 6·88 7·57
	+·0041			
	−·0993	22 22	2 13 20 25	− 0·00 − 5·11 − 6·32 − 7·08
	−·0053			
13 25°	−·1007	20 20	3 12 22 36	− 0·00 − 2·43 − 3·63 − 4·74
	−·0041			
	+·1001	20 20	2 6 14 26 31 41	+ 0·00 2·00 3·91 5·46 5·94 6·64
	+·0047			
	−·1019	20 20	4 9 17 23 36 45 59	− 0·00 − ·75 − 1·56 − 2·00 − 2·75 − 3·13 − 3·75
	−·0029			

No. An.	τ $2(\phi+\phi')$	θ θ'	Time.	$\frac{\phi-\phi'}{\tau}\times10^3$
14 25°	−·1003	20 20	2 10 21 31 42	− 0·00 − 3·99 − 5·95 − 7·03 − 7·23
	−·0044			
	+·0989	20 20	2 7 14 18 23	+ 0·00 2·89 4·75 5·49 6·18
	+·0057			
	−·1021	20 20	5 15 37 57 63 82	− 0·00 − 1·37 − 2·84 − 3·57 − 3·86 − 4·40
	−·0026			
	+·1019		1 111	+ 0·00 7·74
	+·0029			
17 100°	+·1041	22 22	2 12 22 34	+ 0·00 1·04 1·52 1·89
	+·6006			
	−·1033	22 23	1 15 28 40	− 0·00 − 1·66 − 2·21 − 2·59
	−·0014			
	+·1038	22 22	2 9 19 27	+ 0·00 ·79 1·32 1·56
	+·0009			

85. *Mean values deduced.*—The following Table 56 is interpolated from the preceding, and contains mean values of $(\varphi-\varphi')/\tau$, as derived from the two twists, τ, alternately positive and negative. The justification of this mode of obtaining data for a chart is given below. Besides these data Table 56 contains the number and temper, and the electrical constant[1] (specific resistance, s_0, microhms, cc, 0° *C.*), as well as the differences s_0-s_0' and $s_{100}-s_{20}'$, in which the subscripts are the temperatures at which s is taken, and s' is the constant of the normal rod, No. 1. Hence these electrical differences correspond to $(\varphi-\varphi')/\tau$, when $\theta=0°$ *C.* and when $\theta=100°$ *C.*, respectively. For No. 1, $s_0'=18{\cdot}6$, $s_0-s_0'=0$ and $(\varphi-\varphi')/\tau=0$. The values $(\varphi-\varphi')/\tau$ are in the same horizontal row with the temperatures, θ, to which they belong. It is not necessary to distinguish $s_0-s'_0$ and $s_{20}-s'_{20}$, here.

[1] For definition of thermo-electric hardness, cf Bull. U. S. Geol. Survey, No. 14, p. 65.

TABLE 56.—*Values of* $\frac{\varphi-\varphi'}{\tau}\times 10^3$ *for consecutive times.*

Temper.	No. S_0.	S_0-S_0' / $S_{100}-S'_{20}$.	θ.	2m.	5m.	10m.	20m.	30m.	40m.	50m.
Annealed at 450°	2	·8	20	−·00	−·03	−·05	−·07	−·08	−·10	−·10
	19·4	5·9	100	+·00	+·56	+1·12	+1·88	+2·47	+2·90	+3·29
	3	·6	20	−·00	−·06	−·12	−·19	−·23	−·26	−·28
	19·2	5·6	100	+·00	+1·15	+1·97	+3·05	+3·91	.....	.....
Annealed at 360°	4	·4	22	+·00	+·14	+·34	+·57	+·69	+·75	+·81
	19·0	5·5	100	·00	1·58	3·20	4·79	5·92	6·66	7·34
	5	1·5	23	·00	·08	·17	·26	·30	.....	.....
	20·1	6·5	100	·00	1·12	1·97	3·13	4·00	.....	.....
Annealed at 190°	6	10·2	19	·00	·06	·12	·16	·16	.....	.....
	28·8	15·8	100	·00	2·99	7·48	12·72	15·84	17·95	.....
	7	12·3	20	·00	·46	·88	1·31	.....	.....	.....
	30·9	17·7	100	·00	5·10	11·08	18 02	21·90	24·82	.....
	8	12·7	20	·00	·14	·34	·57	·68	.....	.....
	31·3	17·8	100	·00	6·12	12·92	20·54	24·96	28·08	.....
Annealed at 100°	9	18·6	19	·00	·30	·68	1·20	1·56	.....	.....
	37·2	24·2	100	·00	17·48	32·98	.....	.....	.....	.....
	10	15·6	20	·00	·43	·86	1·38	1·71	1·96	.....
	34·2	21·0	100	·00	13·94	27·88	47 26	.....	.....	.....
	11	14·9	21	·00	·32	·69	1 08	1·31	1·48	1·61
	33·5	20·5	100	·00	8·84	19·38	32·64	41·82	.....	.....
Annealed at 30°.	12	20·8	20	·00	2·41	4·24	6·09	7·42	.....	.....
	39·2	.....	.....	.....	.....	.....	.....	.....	.....	.....
	13	18·4	20	·00	1·15	2·27	3·55	4·38	.....	.....
	37·0	.....	.....	.....	.....	.....	.....	.....	.....	.....
	14	22·1	20	·00	2·14	4·00	5·86	7·00	7·91	.....
	40·6	.....	.....	.....	.....	.....	.....	.....	.....	.....

86. *Data of the measurements with platinum alloys.*—Before proceeding to a discussion of these results, I will insert the following set of similar data which I found with alloys of platinum. The normals here are wires of pure platinum, and with these the alloys are to be compared. The plan of comparison and tabulation is the same as explained for steel except that in the present case the temperature, 100°, is made to act on the upper wire without untwisting. The experiment at 100° therefore joins on to the experiment at ordinary temperature in such a way that no adjustment of apparatus is made, further than the change of temperature specified.

The wires n, n' and A are of commercial platinum, purified by long continued fusion on a lime hearth before the oxyhydrogen flame. The other compositions are given. In all cases S_0 is the specific resistance, α the temperature coefficient of the alloy.

As before, like signs of τ and $\varphi-\varphi'$ show that the lower wire (pure platinum, normal) is of greater viscosity.

TABLE 57.—VISCOSITY OF PLATINUM ALLOYS.

Fixed Normal, n', $\left\{\begin{matrix} l' = 26{\cdot}2^{cm} \\ \rho' = 0{\cdot}0215^{cm} \end{matrix}\right\}$ $\theta = 25°$.

No. of wire: l, ρ.	Alloy.	S_θ $\alpha \times 10^3$	$\frac{\tau}{(\phi+\phi)}$	θ'	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$
Normal		13·3	−0·0829	25	0	
n	Pt	2·50	−0·0378		2	+ ·00
l=26·2^{cm}					14	2·26
ρ=0.0215^{cm}					34	3·54
					54	4·16
				100	68	−3·54
					73	−4·24
					85	−4·86
					91	−5·13
					107	−5·49
					120	−5·71
A	Pt	12·0	−0·0748	25	0	
l=26·0^{cm}		2·96	−0·0460		2	0·00
ρ=0·0215^{cm}					17	+3·97
					29	+5·00
					50	+5·98
					75	+6·71
				100	80	+5·20
					102	+5·29
					119	+5·49
					129	+5·78
1	Pt. annealed	18·5	−0·0504	25	0	
l=26·1^{cm}		1·84	−0·0643		2	− ·00
ρ=0·0215^{cm}					19	− ·26
					34	− ·54
					47	− ·54
				100	54	−5·21
					69	−5·46
					91	−5·60
					104	−5·73
2	Pt. annealed	22·1	−0·0805	25	0	
l=26·1^{cm}		1·49	−0·0104		3	− ·00
ρ=0·0214^{cm}					16	− ·32
					39	− ·09
					55	− ·82
**				100	65	− ·00
					75	−1·18
					86	−1·55
3	Pt. annealed	24·7	−0·0905	25	0	
l=26·0^{cm}		1·33	−0·0303		2	+ ·00
ρ=0·0215^{cm}					6	+2·43
					21	+5·67
					45	+7·87
					57	+8·56
				100	63	+2·19
					74	+2·55
					85	+2·63
					117	+2·75
4	Pt. Ag	19·1	−0·0547	24	0	
l=26·1^{cm}		1·87	−0·0660		3	− ·00
ρ=0·0215^{cm}					12	−1·06
					22	−1·49
					36	−1·86
					56	−2·17
**				100	60	− ·00
					70	−7·38
5	Pt. Ag	22.3	−0·0923	25	0	
l=25·9^{cm}		1·5	−0·0285		2	− ·00
ρ=0·0217^{cm}					6	−2·30
					15	−4·85
					30	−7·11
					42	−8·07
					48	−8·56
				100	55	−2·75
					60	−3·02
					75	−3·20
					81	−3·24

** Scale readjusted.

TABLE 57.—VISCOSITY OF PLATINUM ALLOYS—Continued.

Fixed Normal, n', $\left\{\begin{matrix} l' = 26{\cdot}2^{cm} \\ \rho' = 0{\cdot}0215^{cm} \end{matrix}\right\} \theta = 25°$.

No. of wire: l, ρ.	Alloy.	S_θ $\alpha \times 10^3$	$\frac{\tau}{(\phi+\phi)}$	θ'	Time.	$\frac{\phi-\phi'}{\tau} \times 10^3$
6	Pt. Ag	34·0	−0·1003	25	0	
$l = 25{\cdot}3^{cm}$		1·0	−0·0203		1	+ ·00
$\rho = 0{\cdot}0220^{cm}$					6	+3·68
					30	+6·68
					42	+7·18
					52	+7·38
				100	59	+0·8
					64	−1·64
					75	−2·23
					80	−2·99
					100	−4·01
					106	−4·20
7	Pt. Pd	19·4	−0·0738	25	0	
$l = 26{\cdot}4^{cm}$		1·76	−0·0468		2	− ·00
$\rho = 0{\cdot}0216^{cm}$					23	− 8·07
					38	−14·01
					47	−14·90
					54	−15·46
**				100	59	− ·00
					74	− 3·47
					87	− 4·27
					105	− 4.87
					119	− 5·27
8	20·4	1·67	−0·0796	25	0	
$l = 26{\cdot}4^{cm}$			−0·0413		1	− ·00
$\rho = 0{\cdot}0215^{cm}$					6	− 1.84
					21	− 3·18
					30	− 3.51
					41	− 3·83
				100	52	−15·32
					62	−16·15
					79	−16·70
					84	−16·70
n. Normal	Pt.		−0·0867	25	0	
*	*a*		−0·0344		2	− ·00
$l = 26{\cdot}2^{cm}$					9	−2·28
$\rho = 0{\cdot}0215^{cm}$					15	−3·05
					27	−3·90
					33	−4·06
n. Normal			−0·0652	25	0	
†	Pt		−0·0556		2	− ·00
	b				17	−2·48
					44	−3·38
Normal			−0·0443	22	0	
After heating	Pt		−0·0766		1	+ ·00
lower wire	*c*				4	+14·21
thoroughly					14	+32·29
red hot.					28	+42·71
					44	+49·61
Normal			−0·0436	22	0	
After heating	Pt		−0·0773		2	− ·00
upper wire	*d*				7	−15·32
thoroughly					17	−28·57
red hot.					25	−34·64
					43	−42·37
					54	−45·40
Normal			−0·0383	22	0	
After heating	Pt		−0·0826		3	+ ·00
lower wire	*e*				7	+ 3·84
thoroughly					26	+13·52
red hot.					47	+19·18
					55	+20·70
Normal			−0·0396	22	0	
After heating	Pt		−0·0813		3	− ·00
upper wire	*f*				8	− 7·52
thoroughly					13	−12·07
red hot.						
$l = 26{\cdot}5^{cm}$					29	−20·15
$\rho = 0{\cdot}0212^{cm}$					37	−22·77
					46	−25·39

* Without annealing. † After careful annealing (both wires) at red heat. ** Scale readjusted.

DEDUCTIONS FROM PLATINUM ALLOYS.

87. *Viscous effect of alloying.*—The results just communicated for platinum alloys were made first in chronological order, and led to the results already communicated for steel. It will therefore be in place to discuss the purposes of the alloy work and the difficulties encountered in endeavoring to arrive at intelligible results. In Chapter II I inferred from certain results obtained by Dr. Schroeder and by myself independently that wires of small viscosity were proportionately more susceptible to the influence of temperature. It is this proposition which the alloy work was primarily intended to elucidate. Moreover the resistances and temperature coefficients of the alloys were known from earlier investigations,[1] in which the same alloys had been operated upon. Hence I hoped also to see whether any relation between viscosity and electrical resistance would be discernible, a result which in a general way obtains for tempered steel. In other words, if the temperature coefficient of viscous deformation should hold similar generic relations to the amount of deformation that the temperature coefficient of electrical conductivity holds to conductivity, then an investigation like the present might reasonably be expected to lead to results bearing directly on the mechanism of electrical resistance. This is the chief point of view from which the work is undertaken.

The normal wires N and N' were originally identical. After heating both to redness, however, I was surprised to find that the large difference registered at the beginning of Table 57 obtained. The upper wire is more viscous than the lower at 25°, but decidedly less viscous than the lower when 100° is applied to the upper wire, the temperature of the lower—as in all these experiments—being fixed. Yet these results are not sustained by the platinum wire A.

The gold alloys form a series in which mean viscosity tends to increase with electrical resistance; but the behavior in the divers cases is obscure. Again, the silver alloys form a series in which the increase of viscosity with resistance is very decidedly marked. Moreover, the effect of temperature to accelerate viscous deformatian decreases as the viscosity decreases.

Finally these deductions hold for the two palladium alloys.

88. These results are encouraging, notwithstanding the element of vagueness which it is almost impossible to eliminate. The general result is in favor of high electrical conductivity associated with small viscosity and small temperature coefficients. Platinum itself, however, is a marked exception to this observation. Hence to determine the amount of variation of the normals, as well as to enter more closely into the nature of the discrepancy, I made the investigation comprehended in the second part of Table 57. The results obtained show, in the first place, that in consequence of the twisting incident to the examinations

[1] Bulletin U. S. Geol. Survey, No. 54, 1889, p. 143.

of the wires Nos. 1 to 8, the lower wire has gained in viscosity sufficiently to exceed the upper (unused) wire in this respect. This relation is maintained even after both wires are similarly annealed. I then made the experiment of annealing only one of these wires in the way the table indicates. The results are striking. It appears that in every case the freshly annealed wire is enormously less viscous than the unannealed wire; and that this difference of viscosity produced by these mere mechanical means is so large as would wholly mask and obscure the effects of alloying investigated in the earlier part of Table 57. Having thus found how large an error in the observed viscosity may be introduced by even trifling differences of mechanical treatment, I concluded that an investigation into the true effect of alloying would necessarily be of an exceedingly refined character, and would therefore not fall properly within the scope of the present bulletin. Further attempts to study the viscosity of alloys were therefore for the present abandoned.

Whatever may be the effect of alloying on viscosity, it is clear that the enormous electrical effect produced by alloying platinum (resistance increased) and the relatively small electrical effect produced by imparting a strain are quite out of proportion and symmetry with the corresponding viscous effects in the two cases. Again, the effect of temperature in changing viscosity is much too marked to conform with the resistance effect of temperature. These results appear more clearly in the data for steel.

89. *Effect of annealing and hardening platinum.*—In this place, however, the effect of annealing at red heat is of special interest. The two wires N and N' being chemically identical, the effect of annealing on the molecular configuration must be the same in each case. If a thin wire be heated red hot and cooled in air, the result is a strain of dilatation imparted to the wire on cooling. Hence, for this reason alone, the molecular stability of the wire is of a lower order than obtains, cæteris paribus, when cooling takes place with extreme slowness. This is the case of the freshly annealed wire. Again, it is probable, if such a wire is twisted, even over small arcs, that the greater number of the more unstable configurations will be mechanically broken up; for it is clear that the prevailing tendency must be such as to cause the unstable configurations continually to fall to positions of minimum potential energy. If twisting be indefinitely repeated, therefore, the result is very perceptible hardness and elasticity. It is not necessary to recite here the many experiments I made to elucidate these questions. I will confine myself to a statement of results.

In the first place, when two wires as nearly as possible identical (chemically and physically) are compared, the question arises in how far viscosity may vary with the time which elapses *after* annealing. The experiments made showed a slight increase of viscosity with the time given to the molecules to subside after annealing in air. Two identical wires of platinum were annealed, for instance, and then al-

lowed to rest for several hours; after which only one of the wires was again annealed, and the two were at once compared after cooling. This and similar tests indicated small decrease of viscosity of the freshly annealed wire; results, however, by no means comparable with the data of the above table and often obscure.[1]

The sign of the twist of the wires N, N', of pure platinum, compared in the table is the same throughout. The question therefore arises in how far an earlier stage of viscous subsidence simply overtakes a later stage. To determine this it is sufficient to *reverse* the sign of the twist alternately without fresh annealing; or to reverse it with each of the alternate annealings of the upper and lower wire. Experiments made in some number showed that even in this case the results of the second part of Table 57 hold good, the diminution produced being in degree, not in sign. The viscous deformation of freshly annealed wire takes place at a decidedly greater rate even when the viscous motion of the other wire is intensified by an impressed latent strain.

SUMMARY.

All these results are such as follow at once from Maxwell's theory. They show that the effect of twisting is to be referred to the motion of molecules which accompanies it. The molecules, together with their component atoms, are thus placed in new relative positions; therefore unstable configurations during the course of such motion are continually broken up into configurations of smaller potential energy and greater stability. Hence, finally, the observed decrease of viscosity. By reversing the sign of the twist the original configurations can be only partially restored, even for small permanent set, such as is here in question; and the effect of prolonged and repeated twisting is stiffness and constant viscosity, because all the molecules have collapsed into configurations of minimum stability, and the intrinsic molecular energy is the potential minimum compatible with the given conditions.

DEDUCTIONS FOR STEEL.

"ACCOMMODATION" IN GLASS-HARD STEEL.

91. *The phenomena proper.*—Steel wires were used in our earlier work,[2] free from torsion strain. The hard steel wires of the present paper, employed in other researches, may contain twists stored up like residual magnetism. This produces a kind of unilateral symmetry, so far as torsions are concerned; but it is not otherwise objectionable. In critical cases wires free from latent torsion are selected.

[1] The thermal effect without annealing is so nearly negligible as to prove that in Dr. Schroeder's work (Wied. Ann., vol. 28, 1886, p. 369) the observed result is to be ascribed to annealing of hard-drawn wire. Regarding my own work I may say that I am not sure that both wires were kept quite free from tensile stress, the importance of which I did not at the time fully appreciate. In a later research I made a detailed study of the viscous effects of traction and other mechanical stress. (Cf. Phil. Mag. Feb., 1889, p. 155.)

[2] Barus and Strouhal: Am. Jour. Sci., (III), 1886, vol. 32, p. 448; 1887, vol. 34, p. 4.

Turning to Table 55, the individual wires are found to show wide differences of viscous behavior. In No. 2 the viscous subsidence takes place at nearly the same rate for $-\tau$ and for $+\tau$, both at $\theta=20°$ and at $\theta=100°$. In No. 3 the effect of $-\tau$ and $+\tau$ is of different magnitude at 20°, and enormously different at 100°. In No. 4 the effect of $+\tau$ following $-\tau$ is even more phenomenally pronounced at 20° and particularly at 100°. In No. 5 the wires nearly identical at 20° show differences at 100°. In No. 6 this is true in even much greater degree, whereas in No. 7 wires differing considerably at 20° show relatively small differences at 100°. And so I might go through the series. Nos. 13 and 14 are wires originally free from strain (shear); but vagueness also appears in these.

Careful inspection of the tables reveals the law that viscous deformation takes place at numerically greater rates during the even twists than during the odd twists which immediately precede them respectively. Aside from these oscillations, the effect of twisting here (§ 90) is again pronounced increase of viscosity.

Maxwell's theory accounts for the stated vagueness of behavior at once. In two samples of a complex substance like steel the distributions and relations of the unstable molecular configurations will only in very rare instances be physically and chemically identical. The foregoing paragraph shows that such identity is rare even in pure homogeneous metal. (§ 94.)

The effect of twisting alternately in opposite directions is of so great importance in its bearing on Maxwell's theory that I made further special experiments. From these I select the following example, tabulating it as in case of Table 55. The normal No. 1, annealed at 450°, has been described. No. 18, annealed at 25°, or glass-hard, is carefully selected free from latent torsion, having experienced no other strain prior to the examination in Table 58 than that incident to tempering (quenching). There are twelve alternations of twist, indicated by subscripts, and the current time in hours and minutes of each is given. I also give under m the time in minutes which refers specially to the duration of each twist. No. 1 being of greater viscosity, τ and $(\varphi-\varphi')/\tau$ are alike in sign, by agreement.

Experiments made by counter-twisting two glass-hard wires gave results like this, but on a smaller scale. To compare the results of Table 58 perspicuously it is sufficient to construct the differences, $\Delta(\varphi-\varphi')/\tau$, of the respective value of $(\varphi-\varphi')/\tau$, at *two* and *four* minutes after twist is imparted. These are then to be compared in their dependence on current time, as has been done in Fig. 24. Phenomena of this kind were called "accommodation" by Streintz,[1] their discoverer, by Wiedemann,[2] Kohlrausch,[3] and others. The fact that Boltzmann's law contains them is among its chief excellencies.

[1] Streintz: Pogg. Ann., 1874, vol. 153, p. 406.

[2] Wiedemann: Wied. Ann., 1879, vol. 6, p. 512. This work is the most comprehensive of the relevant researches.

[3] *Kohlrausch: Pogg. Ann., 1876, vol. 158, p. 371.* Cf. Schmidt: Wied. Ann., vol. 2, 1877, p. 48.

TABLE 58.—*Viscous effects of twisting glass-hard steel alternately in opposite directions.*

Normal wire No. 1; $l=30^{cm}$ $\rho=\cdot0405^{cm}$.

Remarks.	τ	Time.	m	$\frac{\phi-\phi'}{\tau}\times10^3$
No. 18_1 Annealed at 250.	—·102	9h 13m	0	.....
		15	2	— ·00
		17	4	—1·31
		28	15	—4·07
		35	22	—5·04
No. 18_2.....	+·102	9h 37m	0	.....
		39	2	+ ·00
		41	4	1·59
		52	15	5·17
		60	23	6·45
No. 18_3.....	—·102	10h 2m	0	.....
		4	2	— ·00
		8	6	—1·45
		19	17	—3·28
		25	23	—3·93
No. 18_4.....	+·102	10h 28m	0	.....
		30	2	+ ·00
		36	8	2·04
		41	13	3·04
		48	20	3.86
No. 18_5.....	—·102	10h 50m	0	.....
		52	2	— ·00
		59	7	—1·59
		70	20	—2·73
No. 18_6.....	+·102	11h 11m	0	.....
		13	2	+ ·00
		15	4	·76
		25	14	2·59
		33	22	3·42
No. 18_7.....	—·102	11h 35m	0	.....
		37	2	— ·00
		39	4	— ·52
		56	21	—2·38
		57	22	—2·45
No. 18_8.....	+·102	12h 0m	0	.....
		2	2	+ ·00
		4	4	·59
		20	20	2·62
No. 18_9.....	—·102	12h 24m	0	.....
		26	2	— ·00
		28	4	— ·41
		40	16	—2·38
No. 18_{10}.....	+·102	12h 42m	0	.....
		44	2	+ ·00
		46	4	·55
		54	12	1·76
		63	21	2·55
No. 18_{11}.....	—·102	1h 5m	0	.....
		7	2	— ·00
		9	4	— ·45
		21	16	—1·76
No. 18_{12}.....	+·102	1h 23m	0	.....
		25	2	·00
		27	4	·48
		36	13	1·69
After several days.				
No. 18_{13}.....	—·102	9h 47m	0	.....
		49	2	— ·00
		51	4	— ·62
		60	13	—2·07
No. 18_{14}.....	+·102	10h 2m	0	.....
		4	2	+ ·00
		6	4	·69
		15	13	4·42
No. 18_{15}.....	—·102	10h 17m	0	.....
		19	2	— ·00
		21	4	— ·62
		30	13	—2·21

TABLE 59.—*Viscous accommodation of glass-hard steel. Digest of Table* 58.

Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$	Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$	Twist No.	Time.	$\Delta\frac{\phi-\phi'}{\tau}\times10^3$
1	0m	—1·31	5	97m	— ·69	9	191m	— ·41
2	24	+1·59	6	118	+ ·76	10	209	+ ·55
3	49	— ·83	7	142	— ·52	11	232	— ·45
4	75	+ ·97	8	167	+ ·59	12	250	+ ·48

If the numerics of $\Delta(\varphi-\varphi')/\tau$ in Table 59 be regarded in their dependence on time, the results are seen to oscillate around a mean line of equilibrium. The ordinates of this mean line decrease with time at a gradually retarded rate, until a definite inferior limit is eventually reached. This is very clearly shown by the diagram, Fig. 24. It is curious to note that the largest observed ordinate (time = 0, nearly), is at least three times the limiting ordinate (time = ∞). After 12 twists oscillation has considerably subsided, but it has not ceased; in the same degree the viscosity of the glass-hard rod has reached a fixed maximum.

This complicated phenonomen is at once elucidated by Maxwell's theory. The ordinates of the line around which oscillation takes place, are an index of the degree of instability of molecular configuration, at the time given by the abscissæ. The oscillations are the result of strain

(latent shear, I may call it) imparted to the configurations by the successive twists to which the wire is subjected. Thus if τ be the impressed twist, and $\Delta\tau$ the mean strain left in the configurations at the

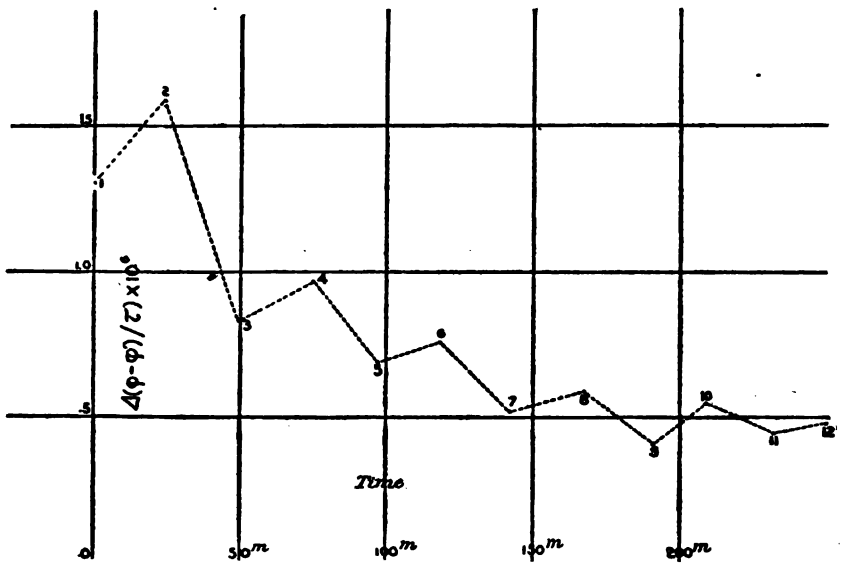

FIG. 24.—Viscous accommodation of glass-hard steel.

instant when τ is removed; and if n be the original relative number of unstable configurations, and Δn the number broken up during the period of the strain τ; then (apart from subsidiary considerations) Maxwell's theory analyzes the effects of alternate twisting in accordance with the following scheme:

	Strain.	Molecular instability.
First twist	$-\tau$	$+n$
Second twist ..	$+\tau+\Delta\tau$	$+n-\Delta n$
Third twist ...	$-\tau+\Delta_1\tau-\Delta'\tau$	$+n-\Delta_1 n-\Delta' n$
Fourth twist..	$+\tau+\Delta_2\tau-\Delta'_1\tau+\Delta''\tau$	$+n-\Delta_2 n-\Delta'_1 n-\Delta''' n$
Fifth twist....	$-\tau+\Delta_3\tau-\Delta'_2\tau+\Delta''_1\tau-\Delta'''\tau$	$+n-\Delta_3 n-\Delta'_2 n-\Delta''_1 n-\Delta''' n$

The variation which Δ undergoes in passing from one twist to the next is indicated by subscripts. Thus $\Delta\tau$, $\Delta_1\tau$, $\Delta_2\tau$, ... is probably a decreasing series; whereas Δn, $\Delta_1 n$, $\Delta_2 n$, ... is an increasing series because reversal of the sign of the twist must be supposed to reconstruct some of the configurations broken up by the preceding twist. The first part of the scheme indicates that the strain in the 2d, 4th, 6th ... twists is necessarily greater than the strain in the immediately preceding 1st, 3d, 5th ... twists respectively, at least at the outset of the experiments. Hence the observed oscillation. Again, the number of unstable configurations must continually decrease, according to the second half of the scheme. Hence the mean line about which the observed viscous deformations oscillate. Finally, experiment shows that

the accelerating effect of $\Delta\tau$ on viscous deformation is greater than the retarding effect of $-\Delta n$. After this, however, the accelerating effect of $\Delta_2\tau - \Delta'_1\tau + \Delta''\tau$, and the succeeding τ-quantities, is always less than the retarding effect of $-\Delta_2 n - \Delta_1 n - \Delta'' n$, and the succeeding n-quantities, respectively.

The scheme admits of simplification; but inasmuch as the period of oscillation is arbitrary, the phenomenon remains indefinitely complex.

92. *Motional effects estimated.*—The second part of Table 58 shows that the viscosity gained in virtue of consecutive alternate twisting of glass-hard steel is permanently gained. The results indicate some recuperation; but the amount is small in comparison with the havoc of configurations made by twisting. Mere molecular motion has therefore permanently broken the more unstable configurations. I will note that the viscous effect of prolonged twisting to and fro in case of glass-hard steel, is of the same order of magnitude as the effect of prolonged annealing at 100°. This indicates the importance of the motional effect in question.

If, following the analogy of steel, I consider annealing a process by which unstable configurations are broken up, I may designate the phenomenon here in question as motional annealing. Experiments for which there is no room here showed that motional annealing is relatively without electrical effect. For increasing rates of twist thick wires show viscous deformation sooner than thin wires. Hence motional break up commences at the external surface where stress is most intense, and proceeds thence toward the axis where stress is least. Thus there appears an essential dependence on the dimensions of the twisted rod. Elsewhere[1] I pointed out that the limits of torsional resilience of soft iron are reached when the obliquity of the external fiber (shear) somewhat exceeds ·003 radians. Regarding the laws of motional annealing, cf. § 101. It follows from the absence of electrical effect, that motional annealing probably presents a pure case of Maxwell's "break up" of configurations of molecules.

93. *"Accommodation" and hysteresis.*—Streintz and Wiedemann's phenomenon "accommodation" admits of representation from a different point of view. Returning to the data of Tables 58 and 59, suppose the experiment so conducted that the twelve twists are immediately consecutive. Suppose, furthermore, that time, m, instead of being reckoned positively onward from the beginning of each of the said twists, were reckoned alternately positive and negative, conformably with the sign of the deformations $(\varphi - \varphi')/\tau$. In this oscillatory march (time as abscissa), since each deformation (ordinate) now begins where the preceding deformation ceased, a continuous series of open cycles is necessarily generated. The positions of these cycles shift at a gradually retarded rate, toward a final very flat cycle, which for the constant values of time and stress is fixed in position and closed.

[1] Am. Jour. Sci. (III), 1887, vol. 34, p. 183.

Cycles here, fixed or not, are expressions of the fact that the "past histories" (in Maxwell's words) of the molecular configurations in the "stress positive" and "stress negative" phase of each cycle are not the same. Shifting is brought about by permanent molecular break up, the amount of which gradually vanishes. In the ultimate and fixed cycle as many configurations are broken during the "stress positive" as are reconstructed in the "stress negative" phase, though they need not be the same configurations.

These considerations suggest a comparison between "accommodation" and Prof. Ewing's[1] "hysteresis," for the purpose of detecting the extent to which like causes are discernible in each phenomenon. Both exhibit a static character. But such comparison would not be fruitful without special and direct experiments; for the *instantaneous* values of stress and of viscosity must be coordinated.

94. *Viscous and electrical behavior compared.*—Having thus discussed one phase of the results in Table 55, I pass to Table 56, which is a digest of the mean values of Table 55, in so far as such a digest can be made. Following the scheme at the end of the preceding paragraph, this comparison should be made after an infinite number of twists have been imparted to each wire. In such a case, however, the original number of unstable configurations has been seriously reduced; so that apart from the annoyance of so time-consuming a method as this, the original properties of the wire are not clearly present in the results. In wires perfectly free from strain, at the outset, the first twist leads to the best indications of the viscous quality. As this condition could not always be guaranteed for the wires of this chapter, I have accepted the mean viscous behavior during the first and second twists as the best available index for comparison. It is sufficient, at least for the present purposes. Again taking the mean for rods of the same nominal temper, I obtain data from which a chart is easily constructed, by representing mean viscous deformation $(\varphi-\varphi')/\tau$, varying with time, for each of the divers degrees of hardness annealed at 25°, 100°, 190°, 360°, 450°, respectively. It so happens that the normal rod, No. 1, is less viscous than the other rods, No. 2 and No. 3, of like temper. Hence the negative numbers in Table 56, which may be eliminated by increasing the other data.

Returning to Table 56, it is clear, inasmuch as viscous deformations are measured differentially, that $(\varphi-\varphi')\tau$ and $s_0-s'_0$ are to be compared. It appears that these quantities increase and decrease together. This is more easily discernible when rods free from strain are compared.[2] The exceptions of Table 56 are due to the fact that the latent strains influence $(\varphi-\varphi')/\tau$ to a relatively much greater extent than $s_0-s'_0$. Again, if $s_{100}-s'_{20}$ and $(\varphi-\varphi')/\tau$ be compared at 100°, Table 56 shows that in this case also the two quantities increase and decrease

[1] Ewing: Phil. Trans. Roy. Soc., II, 1885, p. 523; ibid., II, 1886, p. 361. Prof. Ewing's earlier papers are there given. Cf. also Cohn: Wied. Ann., 1879, vol. 6, p. 403.

[2] Barus and Strouhal: Am. Jour. Sci. (III), 1887, vol. 33, pp. 26, 27.

together. Indeed, the data for 100° are the more uniform, a result due to the fact that at 100° much of the latent torsion is made to vanish because of the annealing effect of 100°. Data of even greater uniformity, cæteris paribus, are to be looked for at higher temperatures.[1]

When a comparison is made between the mean rates at which viscous deformation and resistance increase together with temper, at 20° $((\varphi-\varphi')/\tau$ and $s_0-s'_0)$, and at 100° $((\varphi-\varphi')/\tau$ and $s_{100}-s'_{20})$, it is seen that the mean rate of increase of $(\varphi-\varphi')/\tau$ relatively to $s-s'$ is about ten times as great at 100° as at 20°. This is the phenomenon in virtue of which the viscous behavior of steel, regarded as a test of Maxwell's theory, is almost crucially important. I will endeavor to explain it.

95. *Viscosity at mean atmospheric temperature.*—Dr. Strouhal and I defined the glass-hard state of steel[2] as the stage of temper which undergoes incipient annealing at mean atmospheric temperature. Inasmuch therefore as annealing is demonstrably accompanied by chemical decomposition[3] even at temperatures slightly above mean atmospheric, the molecular configuration of glass-hard steel is always in a state of incipient change.[4] A part, though not the whole, of this change must be of a permanent kind; and I wish to keep in mind that at the temperature of incipient annealing the heat motion is such that broken configurations are sometimes reconstructed.

Inasmuch therefore as glass-hard steel contains more unstable configurations than any other state of temper, at the same temperature, it follows from Maxwell's theory that glass-hard steel, despite extreme hardness, must be the least viscous member of the whole group of tempered and soft steels. This strikingly anomalous prediction of the theory is verified both by the results of Table 56, as well as in earlier work[5] in a way so pronounced as to be irrefragable.

If glass-hard steel is annealed at 100°, the greater number of the unstable configurations are broken up in virtue of the increased molecular vibration at the higher temperature. The cold rod, after annealing, will show increased viscosity in proportion as the number of unstable configurations has decreased. Experiment proves this in a strikingly conclusive way: the increase of viscosity thus produced is marked, being nearly half the difference between the soft and hard states of steel. This, too, is an observation favorable to Maxwell's theory; for

[1] Maxwell's words are (loc. cit.); ". . . but if, on account of rise of temperature . . . the breaking up of the less stable groups is facilitated, the more stable groups may again assert their sway, and tend to restore the body to the shape it had before deformation."

[2] Wied. Ann., vol. 11, 1880, pp. 962, 963.

[3] Barus and Strouhal: Am. Jour. Sci., (III), 1886, p. 276.

[4] During the last three years I have been making experiments on the secular annealing of cold hard steel. The results are very striking, and show that mean atmospheric temperature acting on freshly quenched steel for a period of years produces a diminution of hardness nearly equal to that of 100° C. acting for a period of hours. I examined some twenty rods, the specific resistance of which, within thirty-seven months, has fallen from 46·5 to 42·5, in the case of thin rods (diameter <0·08^{cm}), and from 43·7 to 35·4 in the case of thicker rods (diameter 0·13^{cm}). Freshly quenched pieces showed resistances as high as 50, nearly.

[5] Barus and Strouhal: Am. Jour. Sci. (III), 1887, vol. 23, pp. 25, 26.

if there be configurations with an inherent tendency to collapse at ordinary temperatures, but a small fraction of them will survive at 100°. Moreover the configurations broken up cannot be reconstructed without expenditure of fresh energy (quenching). Since no such energy is ordinarily available, the viscous properties of the annealed rod are of a permanent kind.

Again, if glass-hard steel (or steel annealed at 100°) be softened by annealing at 200°, a greater number of unstable groups will be broken up than in the foregoing case. The viscosity of the cold rod must therefore be considerably greater than that of the hard rod. Experiment proves the viscous increase to be about two-thirds of the whole viscous difference between hard and soft steel. Chemical analysis gives evidence of the occurrence of decomposition; and inasmuch as the unstable groups are permanently broken, the annealed rod shows determinate viscous properties.

If glass-hard steel be annealed at 300°, 400°, 500°, etc., effects of the same nature as those just discussed, but differing from them in the degree of thorough removal of the unstable configurations, will result.

The phenomenon as a whole must be considered continuous, both as regards temperature and time. In proportion as temperature is higher, however, Maxwell's theory predicts that the effects of the same increment of the temperature of annealing, will produce increments of viscosity successively diminishing at a very rapid rate. Supposing molecular configurations originally present in all states of stability, it follows at once that the groups which retain this quality after annealing must very soon vanish when the temperature of annealing is increased. The data prove this in a convincing way: Rods annealed at 300°, 400°, 500°, ... 1000°, show about the same viscous behavior (relatively speaking), notwithstanding the fact that chemical analysis proves that the decomposition incident to the successive application of these temperatures on glass-hard steel continues steadily to increase.[1] Indeed, chemical decomposition above 300° is more marked than below 300°; yet its bearing on Maxwell's theory is now without interest, because in none of the high annealed rods do configurations unstable at mean atmosperic temperature survive after annealing.

96. *Viscosity at* 100°.—Having analyzed the phenomena at mean atmospheric temperature, I come next to consider the conditions of mean relative viscosity at 100°. The glass-hard state must here be withdrawn for consideration in § 98; because such a rod would undergo annealing during the viscous measurements at 100°.

Hard steel annealed at 100° bears the same relations to 100° that glass-hard steel does to mean atmospheric temperature. Hence the reasoning of the preceding paragraph, mutatis mutandis, applies at once. It is merely necessary to bear in mind that 100° is now the temperature of incipient annealing, and that therefore the temperatures

[1] Am. Jour. Sci., 1886, vol. 32, pp. 277, 282.

which produce corresponding viscous effects are proportionately higher. Rods annealed at 200° now occupy about the same relative position that rods annealed at 100° did in § 95; rods annealed at 300° the same relative position as rods annealed at 200°, etc. Moreover, for equal increments of the temperature of annealing, the increment of viscosity shown by the rod at 100° diminishes rapidly as temperature increases, etc.

In one respect the present results differ from the above: the phenomena are here spread out over a scale (roughly estimated) about ten times as large. This means, following Maxwell's theory, that at 100° the number of unstable molecular configurations is relatively much larger than at mean atmospheric temperature. The reasons, though not far to seek, are exceedingly significant. In hard steel, at 100° two causes of molecular instability produce superposed effects. The first is the chemical or carbon instability already discussed; the second cause is purely thermal. Cf. § 102.

The explanation of the diagram for 100° is now clear. Viscous deformation is marked in all the rods examined from annealed at 500° to annealed at 100°; but the deformability increases at a rapid pace in proportion as we pass from softer to harder steel, because in such a march the carburation instability, superimposed upon the thermal instability, increases rapidly. Molecular configurations on the verge of instability are encountered in continually increasing numbers.

97. *Viscosity at higher temperatures.*—The line of argument followed out for 100° applies, mutatis mutandis, at 200°. Results of this kind I published elsewhere.[1] The character of the evidence bearing on all the points in question is here even more pronounced and conclusive. Steel annealed at 200° is in a state of incipient annealing at 200°. Thermal and carburation instabilities of high degree being superposed, the effects are correspondingly large.

Finally above 300° the molecular instability is largely thermal. The behavior of hard steel therefore approaches that of other metals more nearly.[2] The effect of the carburation instability ceases to predominate, and finally vanishes altogether in proportion as the march is made from lower to higher temperatures of annealing.

98. *Annealing and viscous deformations superposed.*—I have finally to touch upon the series of phenomena in which pronounced annealing occurs simultaneously with pronounced external viscous deformation. If, for instance, a glass-hard rod is twisted and then suddenly heated to 100°, the rod is both annealed and suffers deformation in virtue of the applied twist at the given temperature. Conformably with the excessively greater amount of molecular instability which characterizes these experiments, the observed viscous deformation must be proportionately large. This prediction of Maxwell's theory is fully verified by experiment. In the case of the twisted rod postulated the motion

[1] Am. Jour. Sci.: (III), 1887, vol. 34, pp. 14–16.
[2] Cf., Chapter I.

of the image across the field of the telescope is so rapid that Gauss's method of angular measurement is no longer satisfactorily available. I may say without exaggeration that during the small interval of time within which appreciable annealing occurs, a glass-hard steel rod suddenly heated to 300° is a viscous fluid. I have shown[1] that if a glass-hard and a soft rod (cæteris paribus) be identically twisted and heated to 350° the former will have lost all its strain, whereas in the soft rod only about $\frac{1}{3}$ will have vanished. Cf. § 60.

Advantage may be taken of two simultaneous causes of molecular instability in other and purely mechanical ways. Thus molecular instability is produced by drawing soft steel wire through a draw-plate, and the instability increases enormously with the intensity of the strain. Experiments which I made in some number by countertwisting soft and hard drawn steel wire at 30° and at 100° showed results quite comparable in striking interest with the behavior of tempered steel. The character of both phenomena is the same, so that as far as viscous comparisons go the drawn strain replaces the temper strain perfectly. Cf. § 102.

99. *Viscosity and stress.*—Viscosity in the above pages has been considered apart from the stress-intensity under which the deformation takes place. This is liable to lead to confusion, unless the stress relative to which the constants of viscosity are defined be kept clearly in mind, or unless the terms viscosity be applied to solids in the restricted sense of "elastische Nachwirkung." Thus if a glass-hard and a soft steel rod be subjected alike and at ordinary temperature to torsional stress of continually increasing magnitude, a stress value will be reached for which the viscosity of the hard rod will equal, and eventually overtake, the viscosity of the soft rod. I was able to exhibit this phenomenon in even a more striking way at 190°, finding that for rates of twist less than $\tau=3°$ steel rod (radius $=0{\cdot}041^{cm}$) is much less viscous and more susceptible to the influence of temperature in proportion as it permanently harder;[2] whereas for rates of twist greater than $\tau=6°$ steel cæteris paribus is less viscous and more susceptible to the influence of temperature in proportion as it is softer.

Here I may profitably advert to certain considerations postulated in the earlier chapter[3] relative to the association of hardness with resistance against ∞-forces acting through zero-time, and the association of viscosity with resistance against zero-forces acting through ∞-time, all magnitudes being regarded from a relative point of view. "We may reasonably conceive," is there further stated, "that in case of viscous motion the molecules slide into each other, or even partially through each other, so that the molecular configuration is being continually reconstructed; whereas in the other case (hardness) the molecules are

[1] Am. Jour. Sci. (III), 1887, vol. 34, pp. 4, 5. Experiments made by annealing twisted systems.
[2] At 190°, being of course the maximum hardness admissible.
[3] Am. Jour. Sci. (III), 1887, vol. 33, p. 28; or above chapter I.

urged over and across each other . . . ." In the ordinary case of scratching the action is usually accompanied by physical discontinuity of the parts tangentially strained.

Viscosity and hardness may be clearly distinguished by an experimental method as follows: Imagine a round harder body sliding tangentially along the plane of a softer body without rotation. Let there be sufficient pressure on the round body normal to the plane of the softer body to insure cohesion at the point of contact. Then the softer body is subjected to a *simple shear* along the line of scratching. If the motion is sufficiently slow, the soft body may yield viscously and there will be no scratching. If the motion is sufficiently fast, the soft body will generally be scratched. Hence hardness and viscosity are each resistances against simple shearing, according as the tangential motion of the hard body is sufficiently rapid or sufficiently slow, respectively. The conditions for the occurrence of quiescent friction may therefore be stated thus: if there is sufficient time given for the molecules of two bodies to react on each other at the point of contact, the friction is quiescent. If the time be insufficient, friction is kinetic.

The intensity of stress by which the above deformations are evoked was nearly constant and equal to 0·5 kg. on centimeter of arm. This couple, when applied to the given steel rods (radius 0·041^{cm}), is admirably adapted for the exhibition of the nearly *pure* viscous phenomenon, the "Nachwirkung" of Weber and Kohlrausch.

It is just here that certain cardinal distinctions must be made. According to Maxwell's views, viscosity is the same phenomenon in liquids and in solids, and the molecular mechanism by which it manifests itself quite the same in both cases. There is nothing in the theory to induce the reader to limit viscosity in solids to certain special changes of configuration. In solids at high temperatures, and of course in viscous fluids, there is indeed no need of distinction, and viscosity appears as the one property into which the other configuration properties of solid matter eventually merge. In solids at low temperatures, on the other hand, the case is much more complex; and whereas viscosity ("Nachwirkung") still appears as a property common to solids, whether soft or hard, plastic or brittle, these ulterior distinctions, softness, hardness, plasticity (permanent set), brittleness, etc., separate solids by very broad lines. Hence it is improbable that the whole mechanism in virtue of which viscous deformations are possible in viscous fluids is fully of the same nature as that by which viscous motion takes place in solids at ordinary temperatures. Viscosity in liquids is the mean result of divers superposed phenomena, the occurrence of any one of which in a solid would give rise to some special physical property of that solid. From this point of view, since viscosity is independent of the other physical properties above enumerated, and since viscosity (Nachwirkung) is common to solids without exception, I have ventured *to refer it to* such action between contiguous molecules as involves the

least amount of free motion. Viscosity in solids is the result of changes of configuration resulting from localized thermal agitation, and often superinduced by the atomic attraction of contiguous configurations in the manner explained by the Clausius-Maxwell principle.[1]

This premised, further distinctions may be made. Questions arise as to whether such action can be indefinitely repeated without rupture, as in plastic solids, or in viscous fluids; or whether it can not be indefinitely repeated, as in brittle solids, etc. The indefinite repetition of the phenomenon is equivalent to a passage of molecules over or across each other, the phraseology above used in reference to hardness.[2] § 103.

The ideas underlying this paragraph may be summarized thus: In passing from the fluid to the solid state of matter the residual or extramolecular affinities acquire an increased importance relatively to the intermolecular affinities. At the same time the conditions of action have gradually become exceedingly unfavorable. In a liquid under impressed favorable conditions chemical reaction between molecules is demonstrable (electrolysis). In a solid under impressed favorable conditions (strain of dilatation) it is also demonstrable, for instance, in the marked secular annealing of glass-hard steel. It is not necessary for the manifestation of viscosity that the integrity of the molecule be actually invaded; but as the action intensifies one may pass continuously from Maxwell's into Clausius's hypothesis without being able to define the line of transition, at least from the character of the viscous phenomena.

100. *The phenomenon of glass-hardness.*—The observations made in the above paragraphs relative to the visible viscous subsidence of a mechanical strain imposed on a steel rod apply for the complete explanation of the phenomenon of temper. With this purpose in view, it is merely necessary to conceive of hardening or quenching (sudden cooling of steel) as an operation by which a strain of dilatation is imparted to steel. This strain, once supplied, is locked up in the metal in virtue of viscosity.[3] The strained structure of hard steel is proved by the fact that massive pieces of hard steel often explode spontaneously,[4] and by the tendency to rupture during quenching exhibited by the metal. The temper strain may be studied optically and in other ways, in glass, and at low temperatures, even in resin.[5]

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[1] "Betrachten wir ferner das Verhalten der Gesammtmolecüle unter einander, so glaube ich dass es auch hier zuweilen geschieht, dass das positive Theilmolecül eines Gesammtmolecüls zu dem negativen eines anderen in eine günstigre Lage kommt, als jedes dieser beiden Theilmolecüle in Augenblicke gerade zu dem anderen Theilmolecül seines eigenen Gesammtmolecüls hat, etc." Mech. Wärmeth., 1879, vol. 2, 2 Aufl, p. 163. Again, following Maxwell: ". . . . Thus we may suppose that in a certain number of groups the ordinary agitation of the molecules is liable to accumulate so much that every now and then the configuration of one of the groups breaks up, and this whether it is in a state of strain or not. . . . ."

"But if a solid also contains . . . . groups of the first kind which break up of themselves . ." Maxwell, loc. cit.

[2] Cf. Am. Jour. Sci. (III), 1887, vol. 34, pp. 1, 18.

[3] Cf. Bull. U. S. Geol. Survey, No. 14, 1885, p. 88.

[4] Batchelder: Jour. Franklin Inst. (III), 1844, vol. 8, p. 133.

[5] Marangoni: *N. Cim. (III), vol. 5, 1879, p. 116* (Rupert's drops of resin); De Luynes: Phil. Mag. (IV), *vol. 46, 1873, p. 464 (Rupert's drops of glass)*; B. and S.: loc. cit.

Reckoned from the observed volume increase[1] due to quenching, the stress intensity corresponding to the observed strain may be estimated at 10^{10} dynes per square cm. in steel and 10^9 dynes per square cm. in glass. It is thus of the order of the respective tenacities of steel and of glass.

In view of the fact that the viscosity of glass-hard steel is not above that of glass,[2] exceptionally great strain intensity, though impartible, would not be permanently retained. Hence the secular changes of glass-hard steel. Cf. § 95, foot-note. At this point the function of carbon appears. Sudden cooling induces carbon and iron to remain in the combined state in a way favorable to the dilatation in question. Throughout the process of cooling, carbon and iron, at any place within the metal, are united in conformity with the given degree of carburation and with the strain there experienced. In the cold metal, at the given place, strain is to a certain extent permanent and independent of the surrounding medium of steel.[3] Hence if by gradual *secular* annealing of massive glass-hard steel a sufficient number of carbon configurations are broken, stress may increase to an intensity sufficient to rupture the metal explosively.

In our earlier papers on this subject Dr. Strouhal and I were much puzzled to know whether the temper-strain, and in general the phenomena of annealing, were to be interpreted physically or chemically; whether annealing was a case of viscous subsidence of a mechanical temper-strain, or a mere case of decomposition of chemical hardness. In the light of the present advanced conceptions this distinction is superfluous. It makes no difference whether the configuration breaks up into parts chemically different, as carbon and iron (say) in steel, or into parts chemically though not structurally identical, as in homogeneous metals. Viscosity is conditioned by the degree of instability. Again, it is clear that the principles which account for the subsidence of the mechanical strain will also account at once for such chemical decomposition as is here in question, the difference in the two cases being vested in mere details of molecular mechanism. §§ 98, 99.

101. *The phenomenon of annealing.*—However complex the nature of the temper-strain in steel may be, the behavior of hard steel, when subjected to the influence of temperature, offers sufficient proof of its occurrence. The laws of annealing hard steel[4] are as follows:

(1) The annealing effect of any temperature acting on glass-hard steel increases gradually at a rate diminishing through infinite time; diminishing very slowly in case of low temperatures ($<100°$); diminishing very rapidly at first and then again slowly at high temperatures ($>200°$);

[1] Am. Jour. Sci. (III), 1886, vol. 31, pp. 441, 443; 1886, vol. 32, p. 191; 1887, vol. 33, p. 33; Bull. U. S. Geol. Survey, No. 27, 1886, pp. 30–50.

[2] Barus and Strouhal: Am. Jour. Sci. (III), 1887, vol. 33, p. 30.

[3] Bull. U. S. Geol. Survey, No. 35, 1886, p. 42. Structure studied by the density method. Shells consecutively removed by galvanic solution.

[4] *Phil. Mag.*, V, 1879, vol. 8, p. 341; Bull. U. S. Geol. Survey, No. 14, 1885, p. 195.

so that the highest and hardest of the states of temper possible at any given temperature is approached asymtotically.

(2) The ultimate annealing effect of any temperature (time $=\infty$) decreases at a retarded rate with temperature, and practically reaches the limit of variation below 350°.

(3) The ultimate annealing effect of any temperature, $t°$, is independent of the possibly preexisting effects of the temperature $t'°$, and is not influenced by subsequent applications of $t'°$, provided $t > t'$. In case of partial annealing at $t°$ (time finite), this law applies more fully as the ultimate effect of $t°$ is more nearly reached.

Postulating the strain discussed in § 100, these laws follow at once from Maxwell's theory, and the explanation (mutatis mutandis) is identical in character with that given in §§ 95 to 98 with reference to the applied torsion strain. Inasmuch as annealing is accompanied by chemical decomposition, the conditions under which the temper-strain is reduced are those of § 98.

The third law of annealing asserts that the heat effect is analytic, but not in the same degree synthetic. The carbon configuration definitely broken up by annealing does not recombine on cooling. In pure metal, and up to a certain limiting (small) stress, configurations broken up by stress may recombine when stress is released or reversed. § 102.

102. *The temper-strain in other substances.*—In certain comparisons between the strain effect exhibited by glass and by steel,[1] we were led both by gravimetric and by polariscopic observations to this distinction: the strain in hard steel is very perceptibly affected by annealing temperature as low as 50°, whereas in the case of quenched glass (Rupert drop), perceptible annealing is incipient only at 200°. The bearing of this result on the present discussion is manifest: the difference of behavior is due to the absence in glass of anything equivalent to the unstable carbon configuration in hard steel. The case of glass is nearly that of soft steel, and the behavior as regards viscosity in these two instances is similar.

Schroeder's[2] important result has relevancy here: in the case of hard drawn wire (Ag,Fe, german silver) minimum viscosity is found associated with maximum susceptibility to temperature. This is the general deduction from steel for varying intensities both of temper strain and of drawn strain.

103. *Extremes of complex and of simple molecular structure.*—Following the suggestion of § 99, it may be inferred that in case of very complex molecular structure instability of configuration will be a more probable occurrence than in the case of simple bodies, cæteris paribus. Complex structured matter may be looked upon as a solidified mixture of homologous chemical series, with a predominating member to give the sub-

[1] Barus and Strouhal: Am. Jour. Sci. (III), 1886, vol. 32, p. 185; vol. 31, 1886, p. 451.
[2] Schroeder: Wied. Ann., 1886, vol. 28, p. 369.

stance character. Comformably with this view, the complex organic solids,[1] like silk and ebonite, show more pronounced viscous deformation than metals or mineral solids. These known facts are thus in general accordance with the present theory. Nor is it remarkable that a complex substance like glass lies somewhere between hard steel and soft steel in the scale of viscosity.

On the other hand, when the atoms of the molecule are all alike, and the structure of the substance is essentially atomic, we meet conditions favorable to permanent set. This is probably the case with many metals.

104. *Thermal stability of magnetic configuration.*—Maxwell's theory lends itself at once to the explanation of superposition (perfect or imperfect) of viscous motions, inasmuch as the interpretation given is independent of the special peculiarity of the strain to be discussed. I will adduce a few magnetic results which bear upon this point.

Considering the permanent effects of temperature on the residual magnetic induction of hard saturated steel, Dr. Strouhal and I[2] found it necessary to discriminate between two species of magnetic loss:

(1) The direct effect, due simply to thermal action on the magnetic configuration;

(2) The indirect effect, due to the action of temperature in producing mechanical annealing.

These two kinds of loss of residual induction often occur together. Considered separately, the latter, cæteris paribus, is very decidedly the greater in amount, and its character is fully typified by the concomitant phenomenon of mechanical annealing. The former (1) is not only much smaller in relative magnitude, but subsides completely within a much smaller interval of time. In general, the occurrence of permanent magnetism in hard steel, in its thermal relations, is subject to nearly the same laws of variation as those adduced, §§ 94 to 98, for ordinary mechanical strains. Instability of the carbon configuration is more seriously detrimental to magnetic permanence than is instability of thermal configuration.

If the unstable carburation configuration be removed by thorough annealing at 100°, then the cold hard resaturated magnet must show exceptionally good magnetic stability as regards the effects of mean atmospheric temperature. If the saturated magnet is again thoroughly annealed at 100°, the exceptionally good magnetic stability in question is even further enhanced, because the magnetic configurations unstable as far as 100° have now also been removed. Experiment shows the second magnetic loss to be relatively small. The rods carry the maximum of permanent hardness and the maximum of permanent magnetization as far as 100°. This process of consecutive annealing is the one

[1] Cf. Kohlrausch: Pogg. Ann., 1866, vol. 128, p. 414, and many others.

[2] Strouhal and Barus: Wied. Ann., 1883, vol. 20, p. 662.

we proposed when the magnets made are to withstand the effects of atmospheric temperature, of percussion, and of secular time.[1]

106. *Intensity of magnetic configurations.*—In the above paragraphs I have referred to thermal, carbon, and magnetic configurations, using the adjectives merely to designate the chief cause of the instability under special consideration, whereas the configurations themselves were not necessarily different. In the same way I contrasted thermal and motional instability. Thus a carbon and a thermal configuration may be one and the same grouping, considered from different points of view; so may a thermal and a magnetic configuration. The latter phrase is used advisedly, and the rod showing residual magnetic induction supposed to consist of configurations of all degrees of magnetic stability, as well as in all degrees of magnetic intensity. Stability and intensity are the qualities which in the present case correspond to stability and strain, respectively, in the above configurations.

Magnetic stability decreases from hard to soft steel and from soft steel to soft iron, following therefore the inverse order of viscosity; and its character, too, is different from viscosity, the tendency being toward sudden magnetic changes, even when the cause of such change is superinduced by heat. Cf. §104.

The mean magnetic intensity of the configuration must depend on the dimensions of the saturated rod. In the normal case of linear rods this magnetic intensity increases from hard to soft steel[2] and from steel to iron. Hence from one point of view carbon configurations interfere with the occurrence of intense magnetic configurations; from the other point of view magnetic intensity increases in the direct order of viscosity or stability of molecular configuration.

Among methods for elucidating the nature of the magnetic configuration, a comparison of the effect of a magnetic field on torsional rigidity is probably best. Extending the classic researches of G. Wiedemann,[3] I commenced a series of such measurements. In the case of a given field of great intensity, if two identical iron wires, respectively magnetic and unmagnetic, be countertwisted to the same maximum shear (obliquity of external fiber, $\omega=0{\cdot}003$, say), then the product of the detorsion due to longitudinal magnetization and the diameter of the wires is constant and proportional to the product of the shear and the magnetic coefficient of rigidity. This remarkable relation implies that the increment of the twisting couple evolved by magnetization increases as the third power of the radius, cæteris paribus.

[1] Details in Bull. U. S. Geol. Survey, No. 14, chapter VI; or loc. cit.

[2] Strouhal and Barus: Wied. Ann., 1883, vol. 20, p. 621.

[3] Wiedemann: Electricität, 1883, 3d ed. (III), pp. 683 to 698; Barus: Am. Jour. Sci. (III), 1887, vol. 34, p. 180. I believe my researches are the first attempt to interpret these relations quantitatively, and they lead to the law expressed in the text. Other results I will communicate later. (Cf., Chapter IV.)

SUMMARY.

CLAUSIUS'S AND MAXWELL'S THEORIES COMPARED.

107. Summarizing the results of the above paragraphs, I believe the introductory statements to be fully verified. I have shown that the effect of distributing unstable molecular configurations uniformly throughout the substance of a rigid metal like steel is analogous to that of dissolving molecules of acid or of salt in a nonconductor like water. These added molecules are the unstable groups with which Clausius's theory deals. In both cases the effect produced is proportional to the number of unstable groups distributed. If the number be sufficiently increased, the medium will ultimately be a viscous fluid in the one case and an electrolytic conductor in the other. At the outset, pure water typifies the rigid solid.

The applied stress imparts a permanent strain to the solid. Viscous deformation is therefore accompanied by a residual phenomenon, which manifests itself when the applied stress is reversed or removed.[1] In liquids acted on by an electromotive force the analogous reaction is the reciprocating force of galvanic polarization.

Again, Clausius's and Maxwell's theories mutually sustain each other. For if the conception that molecular configurations are present in a solid in all degrees of stability is necessary to explain the behavior of strained solid matter, it follows that configurations of more pronounced instability will be present in electrolytic systems. Conversely, the fact that many solids can be electrolyzed points to the occurrence in these of a very advanced state of molecular instability. To take the concrete example of glass, the same molecular mechanism which at 300° promotes electrolytic conduction, when the solid is influenced by electromotive force, manifests itself at low temperatures as the viscosity of the solid under stress.

[1] Kohlrausch: Pogg. Ann. 1866, vol. 128, p. 419.

CHAPTER IV.

THE EFFECT OF MAGNETIZATION ON THE VISCOSITY AND THE RIGIDITY OF IRON AND OF STEEL.

INTRODUCTION.

108. Mr. Herbert Tomlinson[1] has recently communicated results on the changes of viscosity and of elasticity produced by magnetizing iron. As both classes of data are obtained by the vibration method, it seems not undesirable to attempt to verify them by some static method, and the one described in Chapter II, Fig. 20, is so easily applicable that I have made use of it.

My original purpose was to confine the investigation to measurements of viscosity, inasmuch as such results have an immediate bearing on Chapter III; but I found in the course of the work that the incidental data on the rigidity of iron and steel could be grouped together. Taken collectively in this way, they led to inferences which the well-known and comprehensive researches of Wiedemann[2] fail to point out. I refer to the effect of magnetization on the rigidity of iron and steel as modified by the dimensions of the metal temporarily strained. In this respect, too, the results are supplementary to Chapter III, for the chapter virtually applies a magnetic method to study the character of a strained atomic configuration. I shall show that the increment of rigidity due to magnetization increases at an accelerated rate as the soft, temporarily twisted wire becomes more nearly filimentary. Now, since the said increment is *independent* of the sign of the current in the helix, and, moreover, increases with the current intensity in a way which I have found not seriously irregular, it seems profitable to attempt to utilize this principle for the construction of electric dynamometers.[3] This is the point of view from which much of the present chapter has been written. It also contains a series of results on the rigidity of magnetized steel temporarily strained and varying in temper from extreme hard to extreme soft.

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[1] Tomlinson: Beiblätter No. 3, 1887, p. 176; original in Proc. Roy. Soc., 1886, vol. 40, p. 447, is unfortunately not at my disposal.

[2] Wiedemann: Pogg. Ann., 1858, vol. 103, p. 571; ibid., 1859, vol. 106, p. 161; Galvanismus, 3d ed. (III), 1883, p. 683–698. Less closely allied researches on the effect of magnetization on torsion, etc., are due to Matteuci: C. R., 1847, p. 301, and to Wertheim: C. R., 1852, vol. 35, p. 702, as well as to Wiedemann (loc. cit.), and more lately to Ewing (Proc. Roy. Soc., 1883, No. 228, p. 117).

[3] Cf. p. 177.

VISCOSITY OF MAGNETIZED STEEL AND IRON.

109. *Apparatus and method.*—To make the present measurements it is merely necessary to replace, by an appropriate helix, the heating apparatus described in Chapter II. The two wires to be examined are in the same vertical line, separated by a rigid piece of brass which carries the index mirror. Any desirable rate of twist may be imparted by rotating and then fastening either the upper or the lower end of the system. If both ends be rotated symmetrically in opposite directions, the mirror remains stationary. In this way any reasonable amount of twist may be stored without moving the image of the scale out of the field of the telescope.

The wires of the system were identical as regards length, diameter, and composition; and the arrangement adopted was such that at any time the upper wire might be under the influence of a powerful magnetic field. The helix used for this purpose consisted of ten layers of 230 turns each, doubly wound in such a way as to form two independent partial helices of 115 turns of wire for each layer. For the same current the fields of these partial helices were identical; by connecting them, either differentially or in series, the field obtained was either zero or the maximum for the given conditions. The length of the helix being 20^{cm}, its internal radius $1{\cdot}25^{cm}$, its external radius $2{\cdot}07^{cm}$, the magnetizing force at the center proves to be 1425 c. g. s. units of intensity per c. g. s. unit of current or 142·5 ($g^{\frac{1}{2}}/cs$) per ampère. Current was obtained from five flat Grove cells, in mean intensity of about one Ampère. Hence the iron wires were probably not far from saturation, supposing that a field of 140 c. g. s. units of intensity is sufficient to magnetically saturate soft iron.

Without elaborate precautions it is impossible to produce a strong field for great lengths of time in this way, without perceptibly heating the helix. This introduces a serious error, for the viscous detorsion actually observed is due to a heat effect superposed on a magnetic effect, both of which are of the same order of minuteness. By using a helix like the one above, in which the current may be passed through the two partial coils in the same or in opposite directions, the full heat effect may be observed either with or without the magnetic effect. For when the coils are joined differentially the field produced is zero, whereas the heat generated in the helix is, cæteris paribus, not changed in amount. This is the way in which I endeavored to eliminate the temperature discrepancy.

It is difficult to find two wires which are absolutely identical; after softening some parts of a wire yield more easily to stress than other parts. It is not until the less rigid parts have been stiffened by receiving permanent set that the rate of twist temporarily stored is the same throughout the length of the wire. All viscous motion which is due to differences in the mechanical or chemical properties of the metals may be detected by allowing a series of observations for open circuit to *alternate with* similar series for closed circuit.

110. *Results.*—Table 60 contains results as obtained with steel annealed about midway between soft and hard. Here θ is the temperature of the helix and of the upper wire, θ' the temperature of the lower wire, l and ρ respectively the length and radius of each. $(\varphi-\varphi')$ denotes the amount of viscous detorsion per centimeter per wire (i. e., per two centimeters of the system), in radians at the time h in hours. In other words $(\varphi-\varphi')$ has the meaning already fully defined in § 56, except that in the present case the essential difference of φ and φ' is to be induced by magnetization. τ denotes the rate of twist in degrees imparted to the system at the unmagnetic end. If $(\varphi-\varphi')$ increases or decreases according as the sign of the twist is positive or negative, then the unmagnetic wire is of greater viscosity than the magnetic wire; and vice versa. Intervals of observation corresponding to open and closed circuits are appropriately indicated. Whenever the circuit is closed differentially in the helix so as to produce a zero magnetic field, this is also stated. $(\varphi-\varphi')$ is correct to three or four units of the last place.

The three parts of this table show that the viscous differences in question are invariably minute. In part first the originally less viscous lower wire becomes perceptibly more viscous when the circuit is closed around the upper wire. The apparent effect of magnetization is here a decrement of viscosity. In the second part the wires for open circuit are equally viscous; for closed circuit the results are the same as in part first both as regards sign and amount. The apparent effect of magnetization is again a decrement of viscosity. Part third, finally, contains the interpretation of these results: it is seen that results of the same magnitude and character are obtained when the magnetic field due to the helix (other effects remaining the same) is zero. The viscous effects here observed are therefore wholly due to temperature, and it may be safely inferred that magnetized and unmagnetized steel differ in viscosity by an amount less than is produced by 5° difference of temperature.

TABLE 60.

Viscosity of steel, annealed 360°. $l=30^{cm}$; $2\rho=0{\cdot}083^{cm}$; $\theta'=20°$.

h	$(\phi-\phi')\times 10^6$	θ	Remarks.	h	$(\phi-\phi')\times 10^6$	θ	Remarks.
hours.	radians.	° C.		hours.	radians.	° C.	
0·00	— 0	..		1·10	—21	..	
2·67	—33	..	Circuit open. $\tau=+6°$.	1·12	—10	19	
4·33	—35	..		1·40	—23	23	
24·00	—50	..		1·67	—23	25	Circuit closed. $\tau=-6°$.
25·42	—50	..		1·92	—34	27	
25·60	—35	..		2·08	—38	..	
25·67	—15	..	Circuit closed. $\tau=+6°$.	2·40	—42	28	
25·83	— 3	..		2·80	—49	29	
26·00	+ 7	..		0·00	— 0	17	
26·25	+10	..		0·18	—30	21	Circuit closed; field zero. $\tau=-6°$.
26·75	+15	..		0·43	—46	26	
0·00	— 0	..	Circuit open. $\tau=-6°$.	0·60	—53	28	
1·00	— 3	..		0·85	—58	29	
				1·00	—63	30	
				4·52	— 7	..	Circuit open. $\tau=-6°$.
				23·25	—17	..	

Inasmuch as the steel wire of Table 60 is permanently a magnet after the first induction, sharper results may be looked for in experimenting with iron. As regards viscosity, iron is less susceptible to the influence of temperature than annealed steel or even soft steel; it is more magnetically permeable and it loses its magnetization completely when slightly jarred in a zero field.

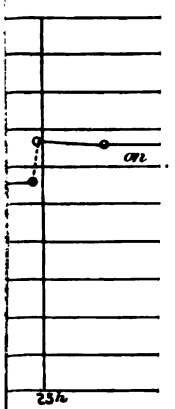
111. Table 61 contains results for soft iron, the arrangement being identical in plan with Table 60.

In the first part of Table 61 $(\varphi-\varphi')$ increases whenever both wires are unmagnetic and decreases at a gradually diminishing rate whenever the upper wire is magnetic. The apparent effect of magnetization is therefore a diminution of viscosity, a result in accordance with the inferences from Table 60. To interpret this apparent result the second part of Table 61 is available. It shows that when the current is passed through the helix differentially, $(\varphi-\varphi')$ increases at the same rate as before, notwithstanding the fact that the field is now zero. Hence the amount of viscous detorsion observed is a temperature discrepancy and no viscous effect due to magnetization is discernible.

TABLE 61.

Viscosity of magnetized iron. Rods Nos. 7, 8, annealed soft. $l=30^{cm}$; $2\rho=0{\cdot}110^{cm}$; $\theta'=20°$; $\tau=-3{\cdot}9°$.

h	$(\phi-\phi')\times 10^6$	θ	Circuit.	h	$(\phi-\phi')\times 10^6$	θ	Circuit.
0·00	0	..	Open.	3·48	+15	26	Closed.
0·57	− 3	..		3·68	+ 4	30	
0·58	+65	..	Closed.	4·05	− 5	34	
0·92	80	33		4·05	−72	34	Open.
1·23	8	34		4·47	−62	29	
1·23	−58	33	Open.	4·52	−55	..	Closed differentially; magnetic field zero.
1·80	−53	28		4·75	−65	32	
1·85	+18	..	Closed.	4·92	−63	33	
2·00	+10	29		5·07	−70	34	
2·17	0	33		5·38	−73	..	
2·48	− 3	34		5·56	−73	..	Open.
2·50	−71	34	Open.	22·30	−50	..	
2·97	−60	29					
3·47	−52	26					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In Table 62, I give similar results with a thinner wire.

TABLE 62.

Viscosity of magnetized iron. $l=30^{cm}$; $2\rho=0{\cdot}033^{cm}$; $\theta'=20°$; $\tau=-3°$.

h	$(\phi-\phi')\times 10^6$	θ	Circuit.	h	$(\phi-\phi')\times 10^6$	θ	Circuit.
0·00	0	..	Open.	5·13	310	..	Open.
0·38	80	..		5·57	328	25	
0·42	189	21	Closed.	23·00	545	18	Closed.
0·50	196	21		23·10	653	..	
0·75	220	26		23·33	645	..	
1·05	245	29		23·67	643	28	
1·38	265	30		24·00	645	30	
1·42	161	30	Open.	24·05	538	30	Open.
1·68	183	28		24·42	550	26	
1·95	203	25		24·95	560	23	
2·17	218	23		24·97	670	..	Closed.
2·18	328	24	Closed.	25·33	660	28	
2·48	334	27		26·17	668	32	
2·88	348	30		26·20	561	..	Open.
3·23	360	32		27·12	580	23	
3·25	255	..	Open.	27·27	690	..	Closed.
3·50	270	..		28·28	685	31	
4·17	298	..		28·35	580	..	Open.
4·20	407	..	Closed.	48·00	740	..	
4·67	410	28					
5·08	420	30					

112. In these results the thermal and magnetic effects are superposed on the continuous viscous motion due to inequalities in the wires, the upper wire being more viscous than the lower wire. In every case, however, this normal viscous detorsion is perceptibly retarded whenever the upper wire is magnetized. It follows conformably with the above results that the viscosity of iron is apparently diminished by magnetization; that the amount of this diminution is no larger than is quite in keeping with the heating effects due to the passage of current through the helix. My results therefore fail to give any satisfactory proof that magnetized and unmagnetized iron differ in viscosity by more than the equivalent of one or two degrees centigrade, at ordinary temperatures.

In Pl. V the results of the above Tables 61 and 62 for soft iron are graphically given, time as abscissa and deformation $(\varphi-\varphi')$, as ordinate. The breaks in the curve show the time at which current was made and broken and the $(\varphi-\varphi')$-effect produced. In Table 61 the two wires are originally identical, as is shown by the "off" branches. The effect of magnetization as apparent diminution of viscosity is shown by the slope of the "on" branches; but the effect of the zero field with current "on" at the end of the curve, is the same in sense and approximate magnitude, as the effect of magnetization. Hence the latter is obscure. Similar interpretation is to be made with reference to the curve for Table 62, in which viscous motion preexists. But this motion, due to greater viscosity of the upper wire (in the helix), is invariably retarded by magnetization. In the second part of this figure the preexisting viscous motion is nil, and the effects are therefore clearer.

In the figure for Table 61, note the tendency to concavity upward in the "on" branches. This is also true of the second half of Table 62.

In Table 61, moreover, prolonged magnetic twisting stiffens the wire; hence the tendency of the "off" branches to slope upward toward the end of the curves.

I am far from wishing to assert, however, that Tomlinson's results are temperature phenomena. It is possible that the marked tendency of soft iron to assume permanent set, and consequently the relatively large viscous motion immediately after strain is imparted, makes the vibration method particularly sensitive in registering the viscous effect of magnetizing iron.[1] But by using static methods and observing in the interval of *gradual* or *purely viscous* deformation, no satisfactory evidence of such an effect is discernible. Moreover, magnetization changes the rigidity of iron and therefore necessarily jars a twisted wire. There result such changes of viscosity as are produced by any sudden vibratory disturbance; changes which of course are purely mechanical, but which may obscure the direct result of magnetic induction.

I may state, in concluding, that inasmuch as Weber's theory associates magnetism with certain rotations of molecule, while divers theories mentioned in Chapter III refer viscosity to a similar mechanism, it would be permissible to look for a marked effect of magnetization on viscosity. The vanishing results of the above paragraphs do not sustain such an inference.

RIGIDITY OF MAGNETIZED IRON.

113. *Definitions and results.*—The effect of longitudinal magnetization on iron or steel twisted within the elastic limits is marked detorsion, increasing in amount with the intensity of magnetic field, increasing also with the rate of twist, at a retarded rate in both instances, toward a maximum. If the sense of the magnetization be reversed (i. e., if the helix current be changed in direction) the amount of detorsion is in general unchanged.[2]

In Tables 60 to 62, discontinuous but perfectly regular variations of $(\varphi - \varphi')$ on passing from unmagnetized to magnetized iron or steel are strikingly apparent. Inasmuch, however, as the differences in question are now to be considered in their bearing on rigidity, and not on viscosity, I will replace $(\varphi - \varphi')$ in subsequent tables by φ. Hence φ is the deflection observed at the index placed at the junction of the two identical wires forming the system, per centimeter of length of each, immediately after one only of the wires is magnetized. Thus φ is evoked and vanishes with the magnetization.

Table 63 contains special results for large rates of twist (τ), and has been drawn up to exhibit the independence of φ of any possible irregularities in the position of the helix as well as the change of sign of φ with the sign of τ. The table shows also that the sign of φ is reversed when the helix is passed from the upper to the lower wire. It follows,

[1] See Wiedemann's remarks on the vibration method, Wied. Ann., vi, 1879, p. 485.

[2] The above phenomena have been elaborately discussed by Wiedemann (Galvanismus, pp. 682–696).

therefore, that φ is not influenced by errors which in my apparatus might result from the increase of length due to magnetization. In other words, in the mechanism adopted, magnetic elongation has no rotational effect. l and ρ denote length and radius each in centimetres. τ is in degrees, φ in radians, as above.

TABLE 63.—*Showing the effect of sign of twist and of position of helix.*

Remarks.	No.	τ	$\phi\times10^6$
Helix symmetrically on upper wire.....	17, 18	+6	−130
	$2\rho=0{\cdot}055^{cm}$	−4·5	+133
	$l=30^{cm}$	+6	−139
Helix symmetrically, on *upper* wire.....	19, 20	−3·0	+93
" +eccentrically, " "	$2\rho=0{\cdot}083^{cm}$	−3·0	95
" −eccentrically, " "	$l=30^{cm}$	−3·0	93
" +diagonally, " "		−3·0	95
" −diagonally, " "		−3·0	95
" high position, " "		−3·0	94
" low position, " "		−3·0	97
" symmetrically, on *lower* wire		−3·0	88
Helix symmetrically on upper wire.....	15, 16	−3·0	+66
	$2\rho=0{\cdot}110^{cm}$	+3·0	−68
	$l=30^{cm}$		

114. These sudden changes in the values of φ due to magnetization are equivalent to an increase of the rigidity[1] of steel, and I shall therefore describe them as such. If T be the torsional rigidity of a wire, i. e., the reciprocal of the amount of twist per unit length per unit moment of twisting couple; and if G be the absolute rigidity of the material, i. e., the reciprocal of the amount of shear per unit of shearing force, then

$$G=\frac{2T}{\pi\rho^4}.$$

Now if in the present apparatus τ' be the rate of twist in radians and φ the change of τ' due to magnetization; if moreover G_m and G be the rigidities of the magnetized and unmagnetized wires respectively; then since the radii (ρ) are identical

$$G_m(\tau'-\varphi)=G(\tau'+\varphi),$$

which if φ is small in comparison with τ' may be written

$$\frac{G_m}{G}=1+\frac{2\varphi}{\tau'}=1\times\mu.$$

115. A final datum of interest is the *obliquity*, ω, of the external fiber, or the angle in radians between the axis of the wire and any tangent of the helix into which a straight surface fiber, or generatrix has been twisted. This is approximately

$$\omega=\frac{\pi\rho}{180}\tau,$$

[1] The retrograde motion formerly observed when the upper wire heated to a high temperature (100°—300°), is cooled to the temperature of the lower wire (Am. Jour. Sci. (III), 1887, vol. 34, p. 17), might in like manner be used to compute the variations of rigidity due to temperature. In such a case, however, the variations of temperature from the high value to the low value must be as nearly instantaneous as possible, otherwise elastic and viscous detorsions will be erroneously confounded.

τ being the rate of twist in degrees. This variable ω is intended to have no more than geometrical significance. It is known that on twisting and again untwisting an iron wire beyond the elastic limits, the fibers do not return upon themselves to their original forms and positions, but that they become irregularly sinuous lines. Perard's[1] investigations on this subject are to the point.

TABLE 64.

Showing the effect of magnetization on the rigidity of soft iron. $l = 30^{cm}$.

τ	Nos. 1, 2. $2\rho = 0{\cdot}234$			Nos. 3, 4. $2\rho = 0{\cdot}136$			Nos. 5, 6. $2\rho = 0{\cdot}090$			Nos. 7, 8. $2\rho = 0{\cdot}110$			Nos. 9, 10. $2\rho = 0{\cdot}070$			Nos. 11, 12. $2\rho = 0{\cdot}048$			Nos. 13, 14. $2\rho = 0{\cdot}022$		
	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$	$\omega \times 10^3$	$\varphi \times 10^6$	$\mu \times 10^3$
0																					
— 0·43	0·8	12	3·2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
— 0·75	1·5	18	2·7	0·9	24	3·7	0.6	42	6·4	0·7	34	5·2	0.5	37	5·6	0·3	60	9.2	....	....	....
— 1·12	2·3	23	2·3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
— 1·50	3·1	30	2 3	1·8	43	3·3	1·2	68	5·2	1.4	54	4·1	0·9	82	6·3	0·6	107	8·2	....	....	....
— 2·25				2·7	49	2 5	1·8	75	3.8	2·2	62	3·2	....	....	....	0·9	116	5·9	....	....	....
— 3·00				3·6	51	2·0	2·3	78	3·0	2·0	65	2·5	1·8	95	3·6	1·2	131	5·0	0·6	86	3·3
— 3·75							....	..	....	3·2	66	2·0	....						....	....	....
— 4·50							3·5	77	2·0				2·7	104	2·7	1·9	148	3·8	....	....	....
— 5·25													3·2	103	2·3	....	....	....	....	....	....
— 6·00																2·5	156	3·0	1·2	166	3·2
— 7·50																3·1	148	2·3	....	....	....
— 9·00																			1·7	205	2·6
—12·50																			2·4	220	2.0
—15·00																			2·9	237	1·8

In Table 64, I have given values for these variables as obtained with soft iron wires of different thicknesses. The intensity of magnetic field has been stated above. Commencing at low values, the rate of twist (τ) is successively increased to the maximum value, which can be imparted, i. e., until, with the occurrence of marked permanent set, the limits of resilience of soft iron are fully reached. After this it was usual to twist the wires further, imparting several thousand degrees of permanent set, whereupon τ was decreased from the maximum to zero. In the table, ω, φ, μ, are means of the values obtained by thus successively increasing and decreasing τ. As before ρ is the radius and l the length of the wires, of which Nos. 1–6 were drawn down from a single piece of wire, Nos. 7–12 from a second piece of wire, Nos. 15–18 from a third piece of wire. A priori, comparison of data is to be made only for wires drawn to different diameters from the same sample of iron;[2] but inasmuch as iron to be ductile must be nearly pure, the results may safely be grouped in a single series. All wires are annealed at red heat in air.

[1] Perard: Revue d'univers. des Mines (2), 1884, vol. 15, p. 346; ibid., 1879.

[2] Imperfections in the wire plate prevented me from drawing all the wires from a single sample of iron.

To this may be added the following data for soft iron filaments drawn from the same wire. ω is the maximum.

TABLE 65.—*Data for filaments of iron.*

No.	2ρ	$\omega\times10^3$	$\phi\times10^6$	$\mu\times10^3$
15, 16	0·032	2·9	212	2·4
17, 18	0·025	2·8	241	2·3

DEDUCTIONS.

116. *Constant fields.*—It has been stated that the wires to which Table 64 refers were all soft. Their diameters vary over the very large interval 0·022^{cm} to 0·234^{cm}, and the rates of stored twist from 0.4° to 15°. Nevertheless the maximum obliquity, ω, of the external fiber is nearly the same for all the rods. In other words, the limits of torsional resilience of soft iron are reached when the obliquity of the external fiber exceeds 0.0032 radians.[1] After this, iron yields to the torsional couple and the result is indefinite permanent set.

Inasmuch therefore as ω is comprehended within about the same interval (0 to 0·003) for all the wires irrespective of thickness, it is expedient to discuss the variation of φ with reference to ω. Indeed, the diagram of φ as a function of ω shows the characteristic family of curves with remarkable terseness. Figure 25 shows that φ increases with ω at a rate which is greater in proportion as the thickness of the wires, 2ρ, diminishes, and which decreases and finally approaches zero when ω is a maximum. The detorsion due to magnetization ceases to increase when the sections of the rod slide on each other. Indefinite twisting beyond the elastic limits has no effect so long as the wire is not appreciably hardened. But it is the dependence of φ on ρ to which I desire principally to advert. The following series of values obtain for ω=0·003.

TABLE 66.—*Effect of dimensions.*

$2\rho\times10^3$=	234	136	110	90	70	48	22
$\phi\times10^6$=	30	50	65	80	105	150	240

To these data add the values on Table 65.

[1] The literature on torsional strains is so voluminous that I can scarcely suppose similar simplifying observations have not been made. But I have found none. Permanent and temporary torsions have been compared with regard to their relations to stress, to the mechanical condition of the material carrying stress, etc., by Wertheim (Comptes Rendus., 1855, vol. 40, p. 411; Ann. de Chim. (3), 1857, vol. 50, p. 195; more elaborately even by Wiedemann (Wied. Ann., 1879, vol. 6, p. 485; ibid., 1879, vol. 7, p. 496; Phil. Mag. (5), 1880, vol. 9, pp. 1, 97, and by Perard (Revue univ. d. Mines, 1879). Reference is also to be made to Tresca (C. R., 1871, vol. 73, p. 1104), to De Saint-Venant, who has investigated the mechanics of ductile substances, and to others. In Wiedemann's last research, correlated values of temporary and permanent torsions are discussed both as they exist immediately after imparting strain and as they exist after an indefinite lapse of time. I have no such comprehensive purpose in view; nevertheless the great convenience of the variable ω is obvious from the way in which I am able to use it.

Recent experiments made with iron wire drawn down finer emphasized the above results. In the case of maximum permanent set the following results were obtained:

TABLE 67.—*Effect of dimensions.*

$2\rho=0{\cdot}018^{cm}$	$10^6\times\phi=280$
$2\rho=0{\cdot}015^{cm}$	$10^6\times\phi=370$

The importance of these results induced me to exhibit their mean variation in a chart. This is done in Fig. 25. In this plate the curves concave to X denote the variation of $\varphi\times10^6$ and $\omega\times10^3$. They make up a family. The other line of the contour of an equilateral hyperbol denotes the variations of $\varphi\times10^6$ with $2\rho\times10$.

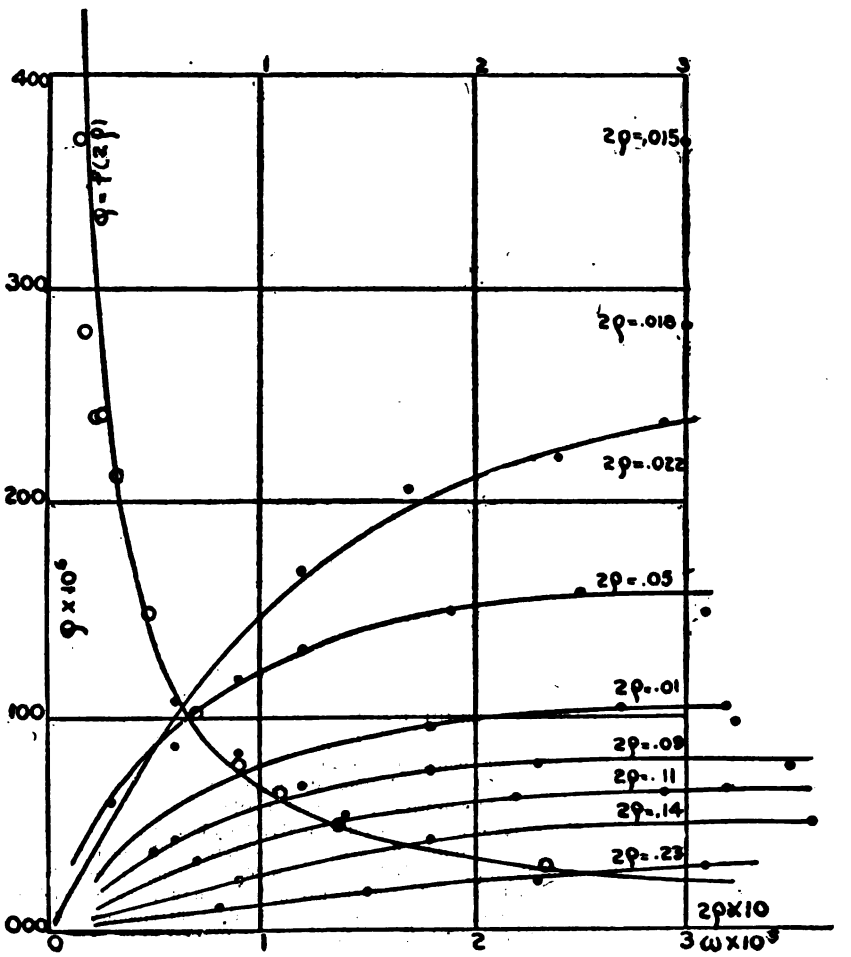

FIG. 25.—Increments of rigidity varying with obliquity of fibers. Increments of rigidity varying with diameter of wire.

The great interest which attaches to these results is the fact that the observed increase of rigidity, as registered by φ, takes place at an exceedingly rapid rate when the diameter of the wires is small. I was not able to make 2ρ smaller than $0{\cdot}015^{cm}$ with the means at my disposal; but copper and platinum wire may be had commercially in diameter as low as $2\rho=0{\cdot}008^{cm}$ or even $2\rho=0{\cdot}004^{cm}$, and no doubt, by skilled hands, iron wire can be much further diminished in diameter than I have drawn it. Here therefore is a method of investigating the magnetics of *filamentary* wires; a method which increases in sensitiveness in proportion as thickness of wire nearly vanishes. From the importance of the properties of filamentary wires this method therefore deserves careful attention.

117. With copper no results were obtained even for $2\rho=0{\cdot}008^{cm}$. φ is zero in all fields.

118. To return again to Fig. 25, I will note that $\mu=\frac{2\varphi}{\tau'}$, τ' being in radians. Now, $\omega=\rho\tau'$, and therefore

$$\mu=\frac{2\varphi\rho}{\omega}=\frac{\varphi\cdot 2\rho}{\omega}.$$

Hence, since experiment shows the approximate constancy of ω and of μ, it follows that $\varphi=f(2\rho)$ is to the same degree an equilateral hyperbola. The mean value of μ taken from Table 64 is, $\mu=2{\cdot}1/10^3$; and the mean value of ω corresponding, $\omega=3{\cdot}2/10^3$. Hence

$$\varphi=\frac{6{\cdot}7}{10^6}\frac{1}{2\rho},$$

and this is the hyperbola with reference to which the points of Pl. V are coordinated.

Again put $\chi=\frac{1}{\varphi}$. Then χ is the *length* of each wire of the system of two wires, which, if the upper wire only be magnetized to saturation, will show a deflection $=1$ radian. It appears therefore that $\chi=\frac{2\rho}{\mu\omega}$, an exceedingly remarkable result.

Hence in the case of a torsion system of two wires, of the same length and radius, but respectively magnetic and unmagnetic, if the twist stored produces maximum obliquity ($\omega\times10^3=3{\cdot}2$) of the external fiber, then the lengths of wire corresponding to a given fixed deflection at the point of junction will vary linearly with the thickness of the wires. These results deserve special tabulation.

TABLE 68.—*Effect of dimensions.*

Mean $\omega=3{\cdot}2/10^3$; mean $\mu=2{\cdot}1/10^3$.

$2\rho\times10$	$\phi\times10^6$	$\chi/10^3$	$2\rho\times10$	$\phi\times10^6$	$\chi/10^3$	$2\rho\times10$	$\phi\times10^6$	$\chi/10^3$
·234	30	33·3	·000	77	13·0	·022	237	4·2
·136	51	19·6	·070	103	9·7	·019	278	3·6
·110	66	15·1	·048	148	6·8	·015	370	2·7

From this table the proportionality of χ and 2ρ clearly appears, as may be seen at once by graphic construction.

119. Since the couple for a given angle φ will vary as ρ^4/l, where l is the length of the wire, it follows that in case of maximum $\omega \times 10^3 = 3{\cdot}2$, the force with which the wire is twisted in virtue of the occurrence of magnetism increases as the cube of the radius. The couple, in other words, is nearly $(.4E)\frac{\pi\rho^4}{2L}\varphi$. And since $\varphi\rho$ is constant for all values of ρ within the limits of observation, and since E the modulus of elasticity, and L the length of the iron wire are also constant, the couple in question becomes

$$L = .4E\frac{\pi\mu\omega}{4L}\rho^3 = \text{const. } \rho^3, \text{ nearly.}$$

120. There are certain curious considerations to which I can only advert here. Suppose the obliquity of the external fiber, ω, to remain the constant maximum. Suppose also the diameter of the iron filament decreases indefinitely until we have reached the diameter of a single molecule. In this case the twisted fiber would be an elementary helix, the spires of which are a continuous succession of oblique molecules. The axis of each molecule is inclined ω, by agreement.

Now it is supposable that if an elementary helix of this kind is placed in a magnetic field of great intensity, that the effect would be (proper adjustment presupposed) to rotate the molecules parallel to the axis of the filament; in other words to reduce ω to zero. In a given system of two countertwisted filaments, such as have been operated on in the above work, the elementary result would be double the rate of twist τ' of the lower unmagnetic filament, and reduce τ' of the upper magnetic filament to zero; thus retaining the same mean rate of twist. More simply the numerical result would be $\tau' = \varphi$. But this ultimate effect runs directly against the datum of experiment: for Table 64 shows that throughout a considerable range of diameter ($2\rho = {\cdot}022^{cm}$ to $2\rho = {\cdot}234^{cm}$), the final value of $\varphi/\tau' = \frac{\mu}{2}$ when $\omega = 0{\cdot}003$, is nearly constant, $\mu/2 = {\cdot}001$ nearly. It is certain that the results show no increase of μ for decreasing ρ.

It is difficult without further experiments to reconcile these conflicting deductions. Probably some light may be obtained by increasing the intensity of field. But (constancy of ω presupposed) the hypothetical result $\tau' = \varphi$ for $2\rho =$ molecular diameter, seems to me an inference of Weber's theory of magnetism, whereas $\frac{\varphi}{\tau} = \frac{\mu}{2}$ const. and independent of diameter conflicts with it.

121. *Intermittent fields.*—The accelerated rate of increase of φ with ρ as exhibited by these data has suggested the remarks already made, viz: since φ is independent of the sign of the current in the helix it is probable that ρ may be taken sufficiently small to render these phe-

nomena practically available for the measurement of induced or alternating currents. The chief difficulties encountered are the phenomena of "accommodation" already very carefully discussed in Chapter III. Twisting by magnetic means has of course the same effect on the unstable configuration, as does twisting by ordinary mechanical couples. To return, however, to the subject in hand, the actual deflection increases with the length of the iron wire. It would be expedient therefore to suspend a light mirror bifilarly from very long filaments of iron and of glass or metal, surrounded by a long cylindrical helix.[1] The rate of twist temporarily stored in the soft iron filament is the maximum within the elastic limits. I give the following example of deflections produced by the current of an ordinary induction coil, acting on a relatively thick and short iron wire.[2] The currents are alternately off and on. The two series were made about an hour apart.

TABLE 69.—*Intermittent currents.*

Nos. 5, 6; $2\rho = 0{\cdot}090^{cm}$; $l = 30^{cm}$; deflection =

30 52	75 85	40 40	80 75	40 35	83 73	40 35	$\phi = 20 \times 10^{-6}$ $\phi = 19 \times 10^{-6}$

In so thick a wire the heat effect of alternating magnetizations soon becomes apparent. The result is temporary diminution of the rigidity of the wire. Much better results are already apparent when the above thin wires are used. For instance (same coil),

TABLE 70.—*Intermittent currents.*

Nos. 15, 16; $2\rho = 0{\cdot}034^{cm}$; $l = 30^{cm}$; deflections =

50 70	180 200	50 60	200 200	70 65	190 200	70; 60;	$\phi = 65 \times 10^{-6}$ $\phi = 69 \times 10^{-6}$

Further discussion of these results (the errors of which are largely due to the apparatus) is not now expedient.

The values of φ in Table 64 are means of five observations with the circuit alternately made and broken. A small amount of permanent detorsion is always imparted to the wire after the magnetism has disappeared, as Wiedemann[3] first pointed out. The following example may be given from very many results of my own. In the case of Nos. 3, 4, the scale readings for currents alternately off and on, were as follows:

[1] It is needless to state that I am well aware of the difficulties here in the way, difficulties which Wiedemann has so carefully digested. In my apparatus, however, all pivot and pulley rotations are avoided. I have also repeated the results relating to fine wires at length with very light mirrors, by which no errors due to an asymmetrical mirror adjustments are encountered. The very small couples which come into play in operating with filamentary wires often make damping by submerged vanes objectionable. I have therefore often discarded them.

[2] The wire plates at my disposal were such that $2\rho = 0{\cdot}02^{cm}$ was the smallest diameter obtainable. But the above series of results are fully sufficient and sufficiently in accordance to justify the inferences drawn.

[3] Wiedemann: *Galvanismus*, p. 669.

TABLE 71.—*Experiments in cycles.*

$\tau=$	0·7°	1·5°	2·3°	2·2°	1·5°	0·7°
(off)	130	110	90	80	50	60
(on)	150	200	185	180	128	100
(off)	80	85	70	70	38	58
(on)	160	188	180	178	130	100
(off)	80	82	70	72	40	60

This is very perceptible in the first part of the measurements where τ or ω increase from zero to the maximum; it generally becomes smaller in amount when ω decreases from the maximum to zero. The method of varying ω from zero to the high value and then from the high value to zero leads to a cycle of results. In the case of Nos. 7, 8, for instance the data ran thus:

TABLE 72.—*Experiments in cycles.*

$\omega\times10^3=$	0·0	0·7	1·4	2·2	2·9	3·2	ω increasing.
$\phi\times10^6=$	5	40	57	63	66	65	
$\omega\times10^3$	3·2	2·9	2·2	1·4	0·7	0·0	ω decreasing.
$\phi\times10^6$	67	64	61	51	28	3	

These observations might perhaps be grouped with Mr. Ewing's[1] "hysteresis." But in some of the many other like experiments which I made there is an element of vagueness.

Table 64 shows finally that the influence of magnetism on the rigidity of soft iron is greatest when ω is zero. It is obvious since φ increases at a retarded rate while τ or ω increase uniformly, that μ must continually decrease. The large values of μ differ considerably, being greater as a rule for smaller diameters. The minimum values of μ obtained are of about the same magnitude, $\mu=0{\cdot}0021$. If the conditions of indefinite permanent set are such that the obliquity of the external fiber, attain a fixed value, then these conditions imply that the rigidity of steel is changed by magnetization by a fixed minimum amount.

RIGIDITY OF MAGNETIZED STEEL.

122. In the following Table 73 I give the values of φ which hold for steel for the large rate of twist $\tau=6°$. The wires are carefully annealed as described elsewhere. Diameter $2\rho=0{\cdot}083^{cm}$. A soft iron wire for which maximum ω is only 0·0021 is also tested for comparison.

The curious result of this table is this, that during the first phase[2] of annealing, the effect of magnetization on the rigidity of steel is almost nil. This effect becomes of marked importance during the second

[1] Ewing: Trans. Roy. Soc., 1885, vol. 2, p. 523–4.
[2] Am. Jour. Sci. (III), 1886, vol. 31, p. 443.

phase.[1] In other words, if we suppose the wire to pass continuously from hard to soft, *the increase of the magnetic coefficient of rigidity, μ, is particularly pronounced after the variations of the thermo-electric, the galvanic and the viscous properties of steel have practically subsided.* μ therefore shows close affinities to the induced and to the residual magnetization of an iron-carburet. Agreeing with Wiedemann's results, μ is invariably smaller for steel than for iron. In general if μ be regarded in its dependence both on ω and on hardness, it appears that the increment of rigidity of an iron-carburet produced by magnetization is greater in proportion as the metal shows greater tendency to assume permanent set—a result which applies for iron and for steel.

TABLE 73.—*Rigidity of magnetized Stubs's steel.* ω=0·0043.

Temper.	$\phi \times 10^6$	$\mu \times 10^6$
Glass-hard	3	0·06
Annealed 100°	4	0·08
" 190°	4	0·08
" 360°	22	0·42
" 450°	25	0·48
Soft steel	41	0·78
Soft iron	95	3·63

[1] In a letter to the Am. Jour. Sci. (III), vol. 33, p. 308, Prof. W. F. Barrett has taken exception to certain remarks made by Dr. Strouhal and myself (ibid., p. 35) on phenomena more or less connected with the second phase of annealing. We regret exceedingly to have overlooked Prof. Barrett's papers. Our object, however, was only to give an enumeration of such observations as had occurred to us *incidentally*. Of Gore's discovery we were aware, and the statement is thus made in the text and in U. S. Geol. Survey, Bull. 14. Owing to a misconstruction of the foot-note in the Journal (p. 35, ‡) "ibid." happens to refer to "Wied. Ann." instead of to "Phil. Mag." The reference is otherwise correct.

We avail ourselves of the present opportunity to state that in Prof. J. A. Ewing's paper on the "effects of stress and magnetization on the thermo-electric quality of iron" (Phil. Trans. II, 1886, p. 361), mention is made of our results only in a final note dated Sept. 17, 1886. Our work was accessibly published much earlier (Wied. Ann., 1881, vol. 14, p. 54; cf. also ibid., 1879, vol. 7, p. 408). We believe we were the first to actually measure Thomson's thermo-electric effect of magnetization as well as to point out its probable relations to the strain of a magnetized rod.

CHAPTER V.

THE CHANGE OF THE ORDER OF ABSOLUTE VISCOSITY ENCOUNTERED ON PASSING FROM FLUID TO SOLID.

INTRODUCTION.

123. Notwithstanding the abundance of the literature on viscosity, nobody has defined the difference between the solid state and the fluid state quantitatively. In case of liquids and gases viscosity can be absolutely expressed with facility, and the data may be stated with considerable rigor. This is not true for solids. The results are relative throughout, no attempt having as yet been made to coordinate their viscous behavior with that of liquids. The present chapter makes use of two methods for this purpose.

In proposing a differential method for studying the viscosity of solids, Dr. Strouhal and I[1] pointed out the way in which the viscosity of solids may be expressed in terms of the respective sectional areas, by which the motion at the junction of two countertwisted wires or rods is annulled. Suppose now that one of the wires is a true solid, whereas the other is a very viscous fluid. Then, since the viscosity of the latter is just capable of being arrived at by transpiration methods, it follows that the viscosity of the solid with which it was countertwisted may also be absolutely expressed. This indicates the first method of procedure adopted. I measured the viscosity of marine glue, by observing the excessively slow transpiration of this substance throughout many months. Knowing this datum, a very thick rod of the cement was compared in viscous behavior with a fine steel wire. §§ 126, 127, 130, 131.

My second method for expressing the absolute viscosity of solids is direct and dynamic. It is capable of yielding results of any desirable degree of rigor, supposing the necessary facilities for work to be given. §§ 134, 135.

GASES AND VAPORS.

124. It is well to note the viscosities η, of typical substances in passing. The viscosity of vapors and gases has been measured by many observers.[2] The data present some curious aspects: Thus, for instance, the viscosity of vapors[3] like ether, is frequently less than the viscosity

[1] Barus and Strouhal: Am. Jour. Sci., 1887, vol. 33, p. 29.

[2] O. E. Meyer: Kinetische Theorie der Gase, Breslau, 1877, p. 138, et seq.

[3] Cf. Puluj: Phil. Mag. (5), 1878, vol. 6, p. 157.

of gases. The absolute values encountered in the present case at mean atmospheric temperature are of the order of $\eta = \cdot 0001$ to $\eta = \cdot 0002$ (g/cs). Cf. § 140.

LIQUIDS.

125. Results are also available in great numbers. The literature is systematized in Landolt and Boernstein's[1] tables, and the data may easily be expressed absolutely by means of Slotte's[2] values of the viscosity of water at different temperatures. Water may be taken as the type liquid. Slotte's value for 20° is $\eta = \cdot 0100$ (g/cs). Cf. § 140.

VISCOUS FLUIDS.

126. *Apparatus.*—Data are wanting.[3]

My experiments were made with marine glue.[4] The method of procedure is simple. A fairly wide capillary tube, *a b*, Fig. 26, provided with a cylindrical open reservoir, *a*, at one end, was half filled with marine glue. The thread extended from the reservoir *a* as far down as the middle, *b*, of the tube. The other (open) end of the tube was introduced into a flask, *d d d d*, from which the air was then exhausted. By this adjustment a pressure of about one atmosphere was continually brought to bear on the reservoir *a*, of the tube *a b*, the other end being in vacuo. To facilitate exhaustion, the flask is provided with a lateral arm, *e*, closed by fusion. A small vacuum gauge, *g g*, held in place by a layer of paraffine, *h*, shows the observer to what degree the vacuum is maintained. It is necessary to cover the rubber stopper *f f* with cement. A number of tubes, *a b*, may be inserted, side by side.

127. *Computation.*—The transpiration equation due to Poiseuille and theoretically corrected by Hagenbach[5] has the form

$$\eta = \frac{\pi P r^4}{8 v l} t - \frac{m}{2^{10} f^3 \pi l} \frac{1}{t} \quad \ldots \ldots \ldots \quad (1)$$

where η is the absolute viscosity of the liquid, v the volume, m the mass transpiring through the capillary of length l and radius r in the time t. In the present case of excessively slow transpiration the corrective member may be neglected. P is the pressure-excess in dynes per square centimetre. Since all the magnitudes are to be expressed in *cgs* units, the dimensions of η are (g/cs).

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[1] Berlin, J. Springer, 1883, p. 153.

[2] Slotte: Wied. Ann., 1888, vol. 20, p. 267. Similar results are obtained by others. Slotte gives the references.

[3] Since this was written Prof. J. D. Everett, of Belfast, has kindly called my attention to certain experiments of v. Obermayer. Looking up this research in the Wien. Ber., (2), vol. 75, 1877, p. 665, I found important data for pitch and storax obtained by a method quite different from mine, but agreeing very well with the order of my results for marine glue, and for paraffine. V. Obermayer finds for pitch at 6·5° $\eta = 21 \times 10^8$ at 10·1°, $\eta = 5{\cdot}3 \times 10^8$, and at 12·2°, $\eta = 2{\cdot}6 \times 10^8$. His datum for storax at 15·5° is $\eta = 13 \times 10^{10}$. Attention may here also be called to some data for glycerine due to Schöttner (Wien. Ber., 1879, vol. 79.)

[4] A valuable cement, being (nominally) a specially prepared mixture of rubber and shellac. It has a pitchy consistency.

[5] Hagenbach: Pogg. Ann., 1860, vol. 109, p. 358. This reference is incidental or I should have to refer to Poisson, Navier, Stokes, Stefan, Helmholtz and others.

In the above form of apparatus l is not constant, and v is measured in terms of the increase of length of the capillary thread ab, Fig. 26. Hence the equation corresponding to (1) (since $dv = \pi r^2 dl$) is

$$2ldl = \frac{Pr^2}{4\eta} dt \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Integrating this equation between 0 and t, and between l_1 and l_2, and again solving for η, there results

$$\eta = Pr^2t/4\ (l_2^2 - l_1^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

an exceedingly simple expression. Here l_1 is the original length ($t = 0$) and l_2 the final length ($t = t$) of the capillary thread. The effect of the cylinder of viscous fluid in the reservoir may obviously be neglected in virtue of its large radius.

By way of digression I may insert another similar and interesting case, viz, that of a viscous liquid like glycerine transpiring in a vertical capillary tube in virtue of the weight of its own column only. In this case $P = (L+l)\ \delta g$, where δ is the density of the liquid, g the acceleration of gravity, L the initial head of the column. Inserting these quantities in equation (2) it becomes

$$\frac{ldl}{L+l} = \frac{\delta g r^2}{8\eta} dt;$$

whence by integration

$$\eta = \frac{\delta g r^2}{8\left(l_2 - l_1 + L \ln \frac{L+l_1}{L+l_2}\right)} (t_2 - t_1)$$

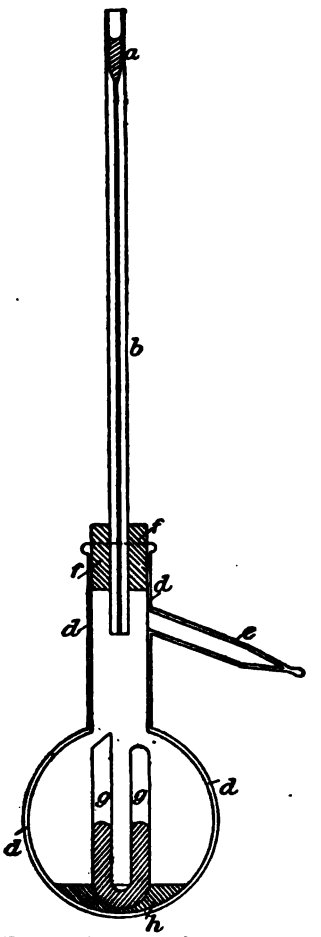

FIG. 26.—Apparatus for the secular transpiration of viscous liquids.

I give an example of the application of this equation in Table 74. Gylcerine is the liquid chosen, a substance which Graham[1] pronounced too viscous for his apparatus, and for which no data are in hand.

[1] Graham: Phil. Trans., 1861, vol. 151, p, 382. His glycerine work was done with "18-hydrates." "The liquid (glycerine) is too viscous to be transpired by means of the bulb and capillary employed in these experiments." Graham, loc. cit.

TABLE 74.—*Viscosity of glycerine.*

$r = .0505^{cm}$; $L = 1.35^{cm}$; $\delta = 1.26$; $\Delta t = 120^{sec.}$

t	l	$Ln\frac{L+l_1}{L+l_2}$	η
sec.	*cm.*		*g/cs*
30	10·07		5·05
		—·86	
150	20·30		
		—·78	
60	12·72		5·07
180	22·75		
		—·62	
90	15·30		5·11
210	25·10		
		—·52	
120	17·80		5·13
240	27·43		
		—·34	
270	29·32		5·53
390	38·60		
		—·32	
300	31·95		5·44
420	40·83		
		—·30	
330	34·20		5·44
450	43·04		
		—·28	
360	36·40		5·43
480	45·22		

The observations though made upon a single descending thread at the end of each half minute are grouped in two batches. The tube was dry; perhaps a moist tube (adhering thin film of glycerine) would have been preferable. To account for the difference of η in the two sets of results is beyond the present purpose. It is noteworthy that each measurement occupies but 2 minutes, even admitting that the tube is unfavorably wide; for in the case of viscous liquids the temperature effect is of paramount importance, and this expedious method therefore has some advantages. The experiment may be varied by noting the descending upper meniscus while the lower end of the capillary is submerged in glycerine.

128. *Data for marine glue.*—Applying equation (3) to the data of the following table, η may be at once computed.

TABLE 75.—*Transpiration of marine glue.*

$P = 10^6$ dynes; $r = .0406^{cm}$; temperature 25°.

Date.	t	l	$\eta \times 10^{-6}$
	sec	*cm*	*g/cm sec*
May 7, 1889, 12h ...	0	3·7	.....
Dec. 7, 1889, 12h ...	18,490,000	7·2	200

This is a remarkable result. Since P in the above apparatus was probably not much smaller than one atmosphere, it follows that η was not much smaller; and yet the substance can easily be fashioned by the fingers, and a sphere if placed on a plane will run out to a flat cake in a few months. This type of viscous fluid is nevertheless 20 billion times as viscous as water at the same temperature.

After long continued transpiration the thread of marine glue shows two strata. The advance portion is amber colored and less viscous,

the rear portion brown, clearly containing most of the shellac. For this reason the observed datum for η is probably somewhat too low. Cf. § 132.

129. *Results for paraffine.*—Paraffine (melting point 55°), treated in this way showed absolutely no transpiration. The tube was nearly of the same bore as above ($\rho = \cdot 0408^{cm}$), and the length of thread $2 \cdot 2^{cm}$. The motion of the paraffine thread must have been below $\cdot 01^{cm}$, or it would have been detected. Hence the viscosity of paraffine must be considerably greater than 2×10^{11} *g/cs*, at about 25°.

SOLIDS.

130. *Method of comparison.*—Having obtained the result of § 128, I proceeded to use it for obtaining the viscosity of hard steel by the method of comparison indicated in § 123. The apparatus was essentially like that used in my earlier experiments.[1] To secure additional safety, however, I introduced the principle of substitution, whereby the steel wire and rod of marine glue were consecutively subjected to known torsion couples in ways otherwise identical. From the enormous viscosity of steel as compared even with marine glue, a beam of this substance something like a decimeter thick would show about the same deformation, cæteris paribus, as a hard steel wire only a millimeter thick. So large a mass of marine glue would have been inconvenient to handle. I therefore used a rod about 4^{cm} thick and suitably apportioned the torsion couples in the two cases. The results are given in the following Tables, 76 and 77. Here 2ρ is the diameter, l the length of the similarly twisted rods. This twist, τ, is given in the first columns, per cm. of length. The applied couples are proportional to 77. N denotes the viscous motion at the index, at the time specified, and is given in scale parts, the distance between mirror and scale being 200^{cm}. Reduction of N is not necessary, since the present method is comparative. The steel wire was twisted alternately in opposite directions to allow for the accommodation. In the other case (Table 77), this precaution is not necessary, the substance being a viscous fluid. Three special twists are given in the table merely to show the behavior.

Other experiments which I made with the cement may be omitted.

TABLE 76.—*Viscous deformation of hard steel wire No.* 1.

$\rho = \cdot 040^{cm}$; $l = 30^{cm}$.

Twist, τ	Time.	N	Twist, τ	Time.	N	Twist, τ	Time.	N
°	*minutes.*	*cm.*	°	*minutes.*	*cm.*	°	*minutes.*	*cm.*
+5·7	0	.....	−5·7	0	.....	5·8	0	.....
	2	·00		2	— ·00		2	·00
	3	·70		3	— ·71		3	·40
	4	1·15		4	—1·25		4	·72
	6	1·87		6	—2·00		6	1·22
	8	2·35		8	—2·58		8	1·60
	10	2·78		10	—3·01		10	1·90
	12	3·15		12	—3·40		12	2·12

[1] Am. Jour. Sci. (III), 1887, vol. 34, p. 2. Pl. I, this Bulletin.

TABLE 77.—*Viscous deformation of marine glue.*

$\rho=2^{cm}$; $l=30^{cm}$.

Twist, τ	Time.	N	Twist, τ	Time.	N	Twist, τ	Time.	N
°	*minutes.*	*cm.*	°	*minutes.*	*cm.*	°	*minutes.*	*cm.*
*1·4	0	·0	1·4	0	·0	1·4	0	·0
	2	2·6		2	2·5		2	2·2
	3	4·8		3	4·5		3	4·2
	4	7·1		4	7·0		4	6·1
	5	9·1		5	9·0		5	8·1
							6	10·1

* This refers to the steel wire (normal). The initial twist of the bar of marine glue is practically zero.

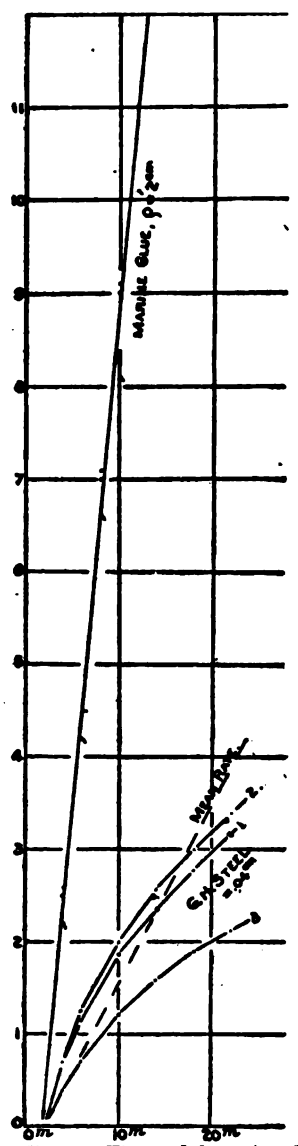

FIG. 27.—Viscous deformation of a bar of marine glue compared with a hard steel wire.

131. *Discussion of results*.—From these tables (graphically constructed in Fig. 27) it appears that the mean rate of motion in case of marine glue is 2^{cm} per minute, whereas the corresponding motion for hard steel is (say) $0{\cdot}4^{cm}$ per minute, this being the mean for the three cases. Further distinction will be made below, §133 et seq., but is here unnecessary. Again, the couple acting on the cement is $1{\cdot}4x$, while the couple in the other case is $5{\cdot}7x$. Since the cement is a liquid, the rate of viscous motion will increase as the couples. Hence for identical couples ($5{\cdot}6x$, say) the motion for marine glue would be 8^{cm}, whereas the rate for steel is $0{\cdot}4^{cm}$, as above. I will now apply the principle[1] mentioned in § 123, whereby viscosities are, cæteris paribus, inversely as the fourth power of the radii. If η' and η be the viscosities of marine glue and hard steel, respectively, then

$$\frac{\eta'}{\eta}=\left(\frac{\cdot 04}{2\cdot 0}\right)^4\frac{0\cdot 4}{8\cdot 0}=8/10^9 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

From Table 75, $\eta'=200\times 10^6\ g/cs$. Hence

$$\eta=25\times 10^{15} g/cs \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where η is the mean viscosity of originally untwisted glass-hard steel, during three consecutive alternate twists of about 12^m duration each.

132. *Errors encountered.*—To fully interpret the result (2) it would have been necessary to compute the η for consecutive times during each of the consecutive twists. This I will do below, where the method used is direct and much more sensitive. The pres-

[1] Am. Jour. Sci., 1887, vol. 33, p. 38.

ent results subserve their chief purpose in furnishing an estimate of the order of viscosity of glass hard steel, which may then be compared with the more detailed statements. Cf. § § 134, 135.

The errors encountered in the above comparative method are these: In the first place, the thread of marine glue which transpires, § 128, is not identical with the rod of this material which is twisted, either as to temperature or composition. Cf. § 128. These difficulties are almost insuperable, though possibly better results might be obtained with pitch. Again, the rod of marine glue, while it is being twisted, is also being stretched by its own weight. This makes the angular measurement difficult, for it is hard to manage a thick rod satisfactorily. Finally, from this cause and the difficulty of obtaining and keeping a rod of the cement free from bubbles, straight and round, the sectional error is considerable. Regarding the above result, I should be surprised if hard steel were less viscous than 10^{16} or more viscous than 10^{17}, under the conditions given.

133. *General remarks on solid viscosity.*—Before giving the results of the following direct method, it is desirable to insert a word on the viscosity of solids generally. In the above case, § 130, while the steel wire is strained by the couple almost as far as the limits of elasticity permit, the rod of marine glue is initially scarcely strained at all. In the latter case, however, the unstable configurations essential to viscous motion are continually supplied in very great number by the ever changing distribution of the heat agitation within the body. In a homogeneous solid (soft steel) these configurations are supplied only in vanishing number. I doubt whether in soft steel the viscous deformation due to instantaneous exceptionally intense heat motion at different points of the solid could be recognized at ordinary temperatures. The case is different when the solid is under stress. Any twist, no matter how small, is accompanied by a proportionate amount of permanent strain. With this a similarly proportionate amount of instability is necessarily associated. Hence it must be carefully borne in mind that the viscosities expressed absolutely below refer to steel in a condition of strain just within the limits of elasticity.[1]

Now it is clear that if the stressed steel be left to itself the number of unstable configurations becomes rapidly less as the time after twisting increases. The viscosity of solids is therefore essentially a time function as well as a strain function.

134. *Apparatus for direct method.*—The apparatus with which the following absolute results were obtained is shown in Fig. 28. *AA* and *BB* are two massive torsion circles, the hollow cylindrical shafts *oo* of which are firmly clamped to supports projecting from the wall of the room. The steel wire *ww* to be tested is tensely drawn between the

[1] I can here merely allude to the recent and suggestive paper of C. H. Carns-Wilson (Nat., vol. 41, p. 213, 1890), in which the behavior of steel near the elastic limits is interpreted in analogy with the well-known circumflexed isothermals of James Thomson.

cylindrical cores *ala'l'* of *AA* and *BB*, and clamped without torsion. To accomplish this the ends of the wire *ww* are bent hookshaped and inserted in a fissure at the ends of the rods *al a'l'*, the clamp screw (shown at *a'*) passing through the loop of the wire. The middle part of the wire *ww* carries a pair of small brass plates *bc*, screwed together

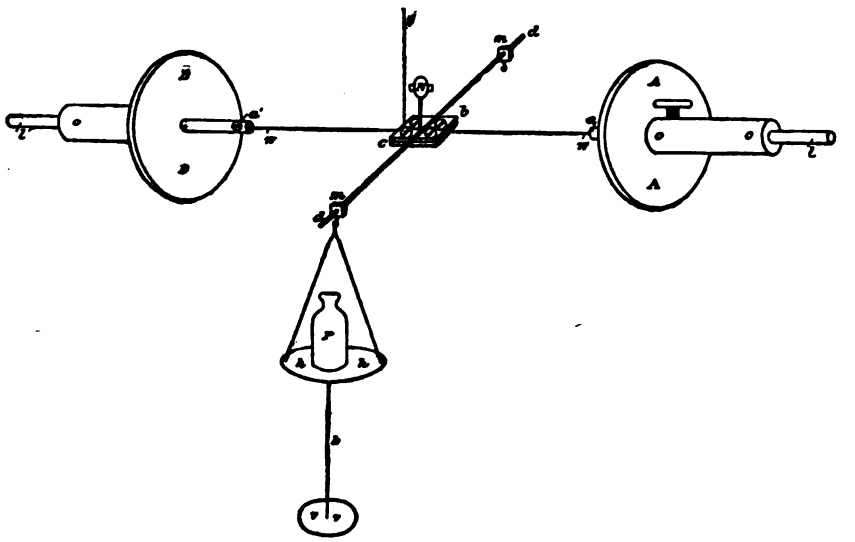

FIG. 28.—Apparatus for measuring the absolute viscosity of solids.

by four screws in such a way as to hold the wire firmly between the plates. A brass rod of screw wire *dd* is soldered to the upper plate, and when in adjustment is at right angles to the axis of *ww*. The rod *dd* is virtually the beam of a balance, and two small nuts *mm'*, symmetrically placed near the ends of *dd*, are provided with hooks, from which a scale pan *hh* may be suspended. The latter carries a light horizontal disk *vv*, to be submerged in water (not shown), with the object of deadening vibrations when the apparatus is in adjustment. The upper plate *bc* also carries an adjustable mirror *N* for angular measurement, as well as an index *fg*, moving across a stationary graduated dial (not shown in figure), by which the amount of twist which holds the weight *P* in equilibrium is roughly registered.

In adjusting the apparatus the scale pan *hh* is removed, and the rods *al* so placed that the lever *dd* is vertical. After thoroughly clamping *al* (care being taken to avoid twisting the wire *ww*), the scale pan is attached at *m'*, and additional weights *P* added, such as hold the lever *dd* horizontal. Hence the two halves of the wire *ww* are twisted 90° each for the whole length. Other twists may be applied by rotating the torsion circles and adding suitable weights *P*.

To fasten the wire between the plates *ab* the lower one is clamped in a vise, and the four screws then fastened securely. There is no rotational sliding here under the given stresses, as is proved by exam-

ining wires of exceedingly high viscosity. Some difficulty is experienced in originally fixing the wire *ww* in place quite free from torsional strain. There is also some flexure. But for wires of the radius given these discrepancies are negligible in comparison with other errors inherent in the wires. In examining the effect of strain on viscosity it would be desirable to connect A and B rigidly together and express the strain in terms of the weight P; but this is beyond the purpose of the present paper.

135. *Method of computation.*—To compute[1] the results obtained with the apparatus just described, let 2φ be the amount of viscous angular motion in radians of any right section of the wire relative to another right section whose distance from the first is the unit of length. Then in the given adjustment the mirror registers an angle corresponding to 2φ; since at each section, though equal angular detorsion takes place in opposite directions, both must influence the mirror in view of the constancy of the twisting couple. Furthermore, suppose that in the plane of a right section there is no shearing. Then $2d\varphi/dt=2C_i$ is the common angular velocity with which the shear is increased throughout the length of the wire. Consider any elementary cylindrical shell whose length l is the effective length of either half of the wire *ww* and whose right section is $2\pi rdr$, where r is the radius of the section. Then the amount of force distributed uniformly over $2\pi rdr$ will be

$$df=\eta\frac{2\pi rdr}{l}l\,2C_ir \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Multiplying by r and integrating both sides between 0 and ρ, the radius of the wire,

$$\frac{1}{2}P\lambda=\eta_i\frac{\pi\rho^4}{2}2C_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where P is the weight at the end of the lever arm λ, by which the system is held in equilibrium. In any given adjustment $P\lambda/\pi\rho^4=A$, and is constant. Hence

$$\eta_i=A/2C_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

In these equations it has been tacitly assumed that $\int\eta r^3dr=\eta_i\int r^3dr$. Under any conditions, therefore, η_i is a mean value for the sections defined by these integrals.

136. *Data obtained.*—With these equations at hand it is not difficult to understand the results of the following tables, 78 to 81. Here ρ is the radius and l the length of each effective half of the steel wire. P is the total force (being the weight plus the weight of scale pan) acting at the end of the lever arm λ (see Fig. 28). The rate of twist is given under τ in degrees, and $2\varphi'$ is the total yield (in degrees) observed at the end of the experiment. N denotes the actual scale reading in the telescope at the time given, and 2φ is the viscous angular motion in radians between two right sections whose distance apart is 1cm.

[1] The quantity 2ϕ is here used conformably with my earlier papers.

In the second half of the tables $2C$ the time rate of change of 2φ is inscribed, and the final column contains the computed viscosity for the time specified. All times are reckoned from the moment at which the twist is applied. To obtain $2C_0$, I availed myself of graphic methods, these being quite in conformity with the mean accuracy of the work. Table 78 contains results for the wire No. 1, already twisted in Table 75 above. Three twists are applied alternately in opposite directions. In Table 79 the same wire is similarly examined after it has been softened by heating to redness and cooling in air. Table 80 supplies data for a new glass hard steel wire, originally free from stored twist. Table 81, finally, contains the viscous constants of a wire tempered at 450°. This is the identical wire with which I made my earlier differential observations.

TABLE 78.—*Absolute viscosity of glass-hard steel wire No. 1.*

$R=200^{cm}$; $l=12{\cdot}9^{cm}$; $P=82\times981$ *dynes*; $\rho=0405^{cm}$; $\lambda=9{\cdot}43^{cm}$.

FOURTH TWIST.

τ / 2ψ	Time.	N	$10^6\times2\phi$	Time.	$2C_t\times10^9$	$\eta_t/10^{15}$
°	*sec.*	*cm.*	*radians per cm.*	*sec.*	*radians per cm. per sec.*	*g/cs.*
+7	0	*Twisted.*	———	500	735	122
	420	·00	0	1000	462	194
	720	1·04	202	1500	310	291
	1020	1·80	349	2000	222	405
	1860	3·20	621	2500	183	491
	2220	3·60	698	3000	150	600
	2820	4·17	808			
	3480	4·65	901			

FIFTH TWIST.

−7	0	———	———	500	910	99
-6	480	·00	0	1000	474	190
	840	1·20	233	1500	347	259
	1320	2·35	456	2000	270	333
	1860	3·29	638	2500	230	391
	2400	4·02	779	3000	210	428
	2940	4·64	900			
	3480	5·20	1008			

SIXTH TWIST.

7	0	———	———	500	467	193
-6	360	·00	0	1000	265	339
	960	1·20	233	1500	193	466
	1260	1·60	310	2000	156	577
	1800	2·10	407	2500	138	652
	2340	2·50	485	3000	126	715
	3120	3·06	593			
	3900	3·53	648			

TABLE 79.—*Absolute viscosity of soft steel, being wire No. 1.*

$R=200^{cm}$; $P=82\times981$ *dynes*; $\lambda=9{\cdot}43^{cm}$; $l=13{\cdot}0^{cm}$; $\rho={\cdot}0405^{cm}$.

HEATED TO REDNESS IN AIR. FIRST TWIST.

$\frac{\tau}{2\phi'}$	Time.	N	$2\phi\times10^6$	Time.	$2C_t\times10^9$	$\eta_d/10^{15}$
°	*sec.*	*cm.*	*radians per cm.*	*sec.*	*radians per cm. per sec.*	*g/cs.*
+7	0	———	———	500	220	409
·4	420	·00	0	1000	89	1010
	900	·40	77	1500	63	1430
	1500	·63	121	2000	47	1920
	2100	·80	154	2500	34	2650
	2700	·92	177	3000	26	3460
	3300	·98	188			
	3780	1·03	198			

SOFTENED. SECOND TWIST.

−7	0	———	———	500	164	550
·5	360	.00	0	1000	116	776
	1020	·50	96	1500	59	1520
	1500	·70	135	2000	40	2250
	1980	·82	158	2500	30	3000
	2520	·93	179	3000	15	6000
	3120	1·00	192			

SOFTENED. THIRD TWIST.

+7	0	———	———	500	138	652
·4	240	·00	0	1000	70	1290
	840	·42	81	1500	40	2250
	1560	·64	123	2000	28	3210
	2100	·74	142	2500	17	5300
	2520	·76	146	3000	14	6400
	2640	·78	150			
	3120	·81	156			

TABLE 80.—*Absolute viscosity of glass-hard steel wire No. 2.*

$l=13{\cdot}0^{cm}$; $\rho={\cdot}0405^{cm}$; $R=200^{cm}$; $P=82\times981$ *dynes*; $\lambda=9{\cdot}43^{cm}$.

FIRST TWIST.

$\frac{\tau}{2\phi}$	Time.	N	$2\phi\times10^6$	Time.	$2C_t\times10^9$	$\eta/10^{15}$
°	*sec.*	*cm.*	*radians per cm.*	*sec.*	*radians per cm. per sec.*	*g/cs.*
7·2	0	———	———	500	660	136·0
·5	120	·00	0	1000	325	277·2
	420	1·86	358	1500	230	391·5
	720	2·70	520	2000	180	500·0
	1080	3·35	644	2500	140	643·0
	1620	4·10	789			
	2100	4·58	881			
	2580	4·95	952			
	3000	5·18	996			

TABLE 80.—*Absolute viscosity of glass-hard steel wire, No. 2*—Continued.

GLASS-HARD. SECOND TWIST.

τ / 2ϕ	Time.	N	$2\phi \times 10^6$	Time.	$2C_t \times 10^9$	$\eta_t/10^{16}$
°	*sec.*	*cm.*	*radians per cm.*	*sec.*	*radians per cm. per sec.*	*g/cs.*
7·2	0	———	———	500	683	121·4
·6	240	·00	0	1000	392	229·5
	600	1·44	277	1500	285	316·0
	900	2·20	423	2000	240	375·0
	1260	2·88	554	2500	205	439·0
	1800	3·65	702			
	2100	4·04	777			
	2460	4·50	865			
	2700	4·70	904			
	3000	5·02	965			

GLASS-HARD. THIRD TWIST.

———	0	———	———			
———	240	·00	0			
	600	1·17	225			
		Wire breaks spontaneously				

TABLE 81.—*Absolute viscosity of steel annealed at* 450°, *wire No.* 15.

$l = 13{\cdot}6^{cm}$; $\rho = {\cdot}0405^{cm}$; $R = 200^{cm}$; $P = 82 \times 981$ *dynes*; $\lambda = 9{\cdot}43^{cm}$.

TWISTED INDEFINITELY.

τ / $2\phi'$	'Time.	N	$2\phi \times 10^6$	Time.	$2C_t \times 10^9$	$\eta_t/10^{16}$
°	*sec.*	*cm.*	*radians per cm.*	*sec.*	*radians per cm. per sec.*	*g/cs.*
+7°	0	———	———	500	177	508
·1	240	·00	0	1000	69	1300
	720	·51	94	1500	40	2250
	1200	·71	131	2000	32	2810
	1860	·86	158	2500	25	3600
	2520	·95	175	3000	20	4500
	3000	1·01	186			

NEXT TWIST.

−7°	0	———	———	500	111	811
·2	240	·00	0	1000	46	1950
	600	·26	48	1500	40	2250
	1200	·43	80	2000	34	2650
	1740	·54	100	2500	31	2910
	2580	·68	125	3000	30	3000
	3240	·81	149			

NEXT TWIST.

+7°	0	———	———	500	180	500
·2	240	·00	0	1000	82	1100
	660	·48	88	1500	57	1570
	1260	·78	143	2000	48	1870
	1740	·92	169	2500	45	2000
	2520	1·12	206	3000	42	2140
	3120	1·26	232			

Some few irregularities are introduced into the above data, from the fact that vibrations could not be rigorously excluded. Inasmuch as vibration increases the rate of twist periodically, it thus supplies a greater number of instabilities than exactly correspond to the mean twist (position of equilibrium) in question. Hence viscosity is decreased by vibration.

In case of No. 15 and No. 2, etc., the rate of twist of the two halves of the wire *wiw* (Fig. 28) was possibly not quite the same. Hence the viscous motion would also be slightly too large. In case of different mean lengths l, in two different wires, the rate of twist for the same load P would again be different, thus introducing small discrepancies. Finally for No. 15, which had become somewhat worn after long use, the load P probably strained the wire too near the elastic limits. This supplies fresh instabilities by which viscosity is successively decreased from twist to twist and accords with the results actually obtained. Hence it is best to accept the behavior of the softened wire No. 2 as typical of No. 15. Steel annealed at 450° and at 1000° is of equal viscosity, as I have shown in numerous experiments.

DISCUSSION.

137. *Retrospective.*—Turning first to the values φ, it is seen at once that they substantiate the results of my earlier papers throughout.[1] They need not therefore be further commented on here. Table 81 perhaps has special interest, since the φ here contained is the datum for the normal wire formerly used. With this datum in hand, the results of the earlier papers may easily be reduced to absolute values, for I have endeavored to make the angles τ of the same value in both cases, so that φ/τ may be comparable at once.

138. *Spontaneous breaking.*—The spontaneous breaking of the glass-hard wire in Table 80 is worthy of remark. It occurred during the third twist, and at a time when the wire was in no way interfered with. This corresponds to the spontaneous explosion of tempered projectiles frequently observed. It also corresponds to the spontaneous rupture of stressed glass, whether the stress be stored internally or applied externally. I have observed this interesting phenomenon in glass under a great variety of conditions. In all cases there is gradual molecular change, or slow viscous yielding to the point of rupture.

139. *Time variation of absolute viscosity.*—The chief results of Tables 78 to 81 are the values η_t, whether they be regarded as time functions or as exponents of the degree of solid state. In Pl. VI, I have therefore constructed them graphically. As an inspection of the figure shows at once, both the viscosity and its rate of increase with time are greater in case of hard steel (Tables 78, 80) than in soft steel (Tables 79, 81). After about an hour's time the final viscosity of hard steel may be quite as

[1] Am. Jour. Sci. (III), 1866, vol. 32, p. 181–192, and 1887, vol. 33, p. 20–36.

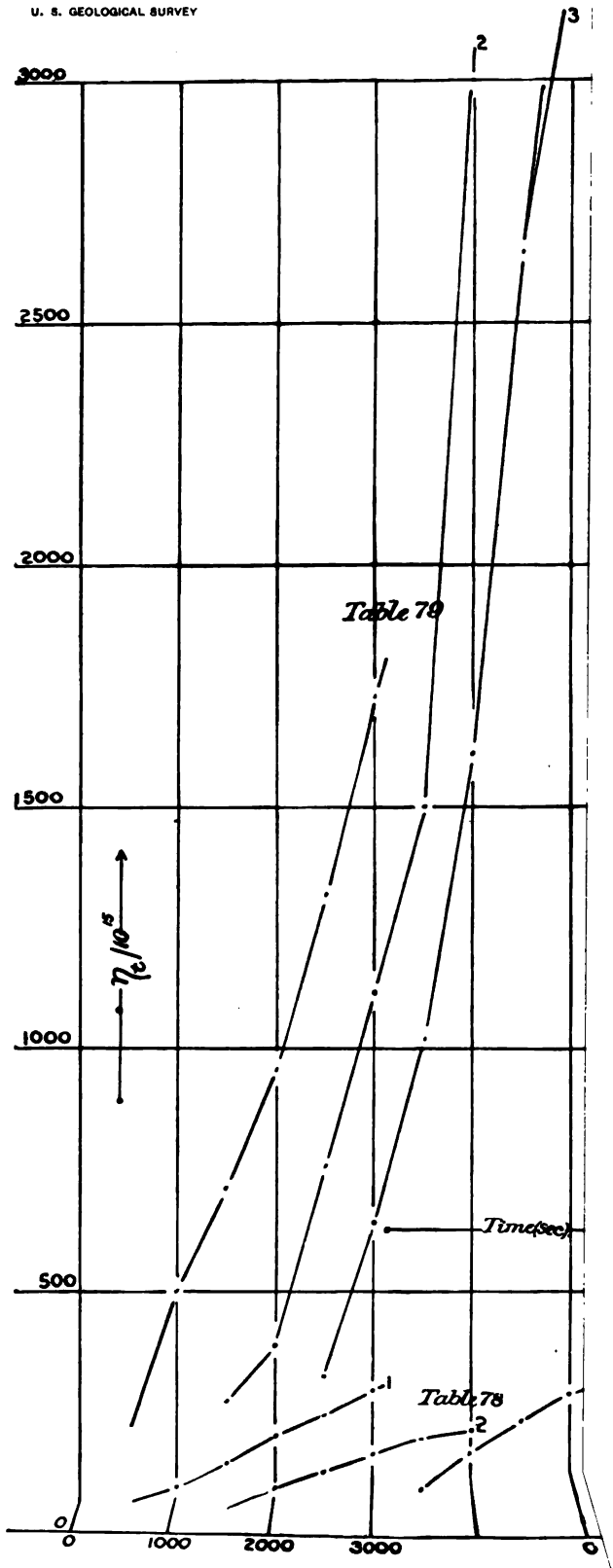

CHART SHOWING THE ABSOLUTE VISCOSITY OF HARD STEEL (TA

large as the initial viscosity of soft steel. For equal times after twisting, the viscosity of soft steel is enormously the greater.

The curves show no pronounced curvature, being in part convex and in part concave. This is particularly clear in the case of hard wires, where the viscosities are smaller, the viscous deformations large, and the observations therefore, as a whole, much more accurate (Tables 78, 80). The extended curves (Tables 79, 81) for soft wires, on the contrary, are less certain, because the viscous deformation is proportionately smaller. Hence I may regard the promiscuous irregularities of the curves of Pl. VI due to errors of observation and construction. It is exceedingly difficult to draw tangents correctly. Again, the observations are hampered by vibrations, etc., in the way indicated at the end of § 136. According to Kohlrausch's law,[2] $-d\varphi/dt=a\varphi/t^n$, where a and n are constants. In case of small torsions, or during short times, the simple relation $-d\varphi/dt=a\varphi/t$ suffices. Thus the character of the curves of Fig. 33 may be considered linear during the first 3000 sec. after twisting. Viscosity therefore increases proportionally to time, at the rates expressed in the following Table 82:

TABLE 82.—*Rate of increase of the absolute viscosity of steel.*

Hard steel.	Twist.	10^{-12} η/sec	Soft steel.	Twist.	10^{-12} η/sec.
		g/cs²			g/cs²
Tab. 4	+4	220	Tab. 5	+1	1200
	−5	140		−2	1400
	+6	240		+3	1900
Tab. 6	+1	230	Tab. 7	+1	1500
	−2	140		−2	1200
				+3	1000

Table 82 shows the mean rate $\eta/sec.$ for hard steel to be 194×10^{12} and its mean viscosity η at 500 *sec.* to be 140×10^{15}; for soft steel $\eta/sec.=1400\times10^{12}$ and mean viscosity at 500 *sec.*, $\eta=570\times10^{15}$. The general explanation of these results has been indicated in §133. In a liquid or a viscous fluid under moderate stress the instabilities are supplied by the mere thermal agitation at ordinary temperatures at the same rate in which they are used in promoting the viscous motion. Hence viscosity is constant at a given temperature. In a solid this is not the case; instabilities are here expended at a rate decidedly greater than the small rate of continuous supply. Thus viscosity decidedly increases with time. Suppose therefore a substance of initially greater viscosity to start on its viscous deformation at an instant when the viscosity of a substance of initially smaller viscosity has been increased by time to the initial value of the former case. This can be realized by twisting the soft steel about an hour after the hard steel rod has been twisted. Then in the succeeding times, even though the substance of greater and the substance of less viscosity start at a stage of equal viscosity, the vis-

[2] Kohlrausch: Pogg. Ann., vol. 128, 1866, p. 210.

cosity of the former will rapidly overtake the viscosity of the latter; for the supply of instability due to temperature alone is continuously greater in one case than in the other.

140. *Solidity of the three states of aggregation.*— Summarizing the results of the above paragraphs, the viscosities of the three states of aggregation may be expressed in terms of the absolute *g/cs* scale as follows:

TABLE 83.—*Viscosity in its variation with the state of aggregation.*

Gases and vapors.		Andrews's critical state.		Liquids. ‡		Viscous fluids.		Solids.
Substance.	η	Substance.	η	Substance.	η	Substance.	η	
*Ether, 0°	$6{\cdot}8 \times 10^{-5}$	†	†	‡ Ether, 30°	9×10^{-4}	Marine glue	4×10^{8}	Paraffine, (m. p. 55°) at 20°. } $>4 \times 10^{11}$
*H_2, 0°.	$8{\cdot}7 \times 10^{-5}$			‡ Ether, 10°	$1{\cdot}9 \times 10^{-3}$			
*Air, 0°.	$1{\cdot}75 \times 10^{-4}$			‡ Water, 97°	$3{\cdot}0 \times 10^{-3}$			†† Hard steel, glass, etc. } 10^{17} to 10^{18}.
†O_2, 0°.	$2{\cdot}12 \times 10^{-4}$			‡ Water, 20°	$1{\cdot}00 \times 10^{-2}$			
				Glycerine**	5			†† Soft steel. } 6×10^{17} to 6×10^{18}.
Range ..	10^{-5} to †	Range	† to †	Range	† to 10^{2}	Range ..	10^{8} to 10^{11}	Range ... 10^{11} to 10^{20}

* Puluj: loc. cit.

† O. E. Meyer: loc. cit., p. 142.

‡ Landolt and Boernstein's tables (loc. cit.) and Slotte (loc. cit.).

** Rough measurement of my own, § 127.

†† During the first hour (500 to 3,000 seconds) after twisting just within the elastic limits.

The limits here defined are of course somewhat arbitrary. They will be made more definite when a greater number of bodies lying on the boundary between the classes have been examined. Information is notably lacking in relation to Andrews's critical temperature, which, in the light of the context of Table 83, is particularly interesting.[1] It is not improbable that the critical temperature may be definable by a narrow limit of viscosity, quite independent of the substance operated on. What this limit will probably be I do not venture to assert, seeing that the viscosity of gases decreases on cooling, whereas that of liquids increases on cooling.

Table 83 gives the positively astounding range of variation of η, the chief variable of our material environment—a variable which throughout the whole enormous interval nowhere fails to appeal to our senses. Knowing these data, it will be possible to look somewhat into the insides of solids and to express the existing state of instability statistically. But this calls for an application of more searching mathematics than I am justified in attempting.

[1] Professor Warburg has had the kindness to refer me to an elaborate paper by himself and v. Babo, in which the viscosity of carbon-dioxide passing continuously through the critical temperature is elaborately considered. (Wied. Ann., vol. 17, 1882, p. 390.) Unfortunately, I can here do no more than call attention to this valuable contribution, which was inadvertently overlooked in my original study of the subject. Warburg and v. Babo's results are such as conform with the substance of the above text and I am glad to acknowledge that they were the first in the field to approach the question.

In concluding, I may state that though I am cognizant of the reasons which induced Sir William Thomson to apply the word viscosity to the phenomena of the present paper, I wish he had chosen some other term. Viscosity is misleading. Undoubtedly a substance which is infinitely viscous is solid, for the parts of such a body are stuck together beyond the possibility of permanent yielding. This truth, however, is of the kind which Gauss[1] in referring to Lagrange's extension of the principle of least action, called "mehr witzig als wahr." Unfortunately the impressions conveyed in speaking of a very viscous body and of a solid body are different. I do not know, but I think solidity would have been a better word than viscosity.

[1] Cf. Klein: Die Principien der Mechanik, Leipzig, Teubner, 1872, p. 88.

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THE

MINERALS OF NORTH CAROLINA

BY

FREDERICK AUGUSTUS GENTH

WASHINGTON
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1891

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY,
Washington, D. C., July 31, 1890.

SIR: I have the honor to transmit herewith the manuscript of a report by Prof. F. A. Genth, of Philadelphia, upon the minerals of North Carolina. I request that it may be published as a bulletin of the U. S. Geological Survey.

Very respectfully,

F. W. CLARKE,
Chief Chemist.

Hon. J. W. POWELL,
Director.

PREFACE.

The present bulletin is essentially a new edition, revised, corrected, and much enlarged, of a report published by the Geological Survey of North Carolina in 1881[1]. Since that time there has been great activity in developing the mineral resources of the State; and by the reopening of old localities and the discovery of new deposits, a goodly number of species have been added to the old lists. To mineralogists North Carolina has become classic ground, especially as regards the mines of mica and corundum; the localities for modified quartz; the gold sands of Burke, McDowell, and Rutherford Counties; and the emerald and hiddenite discoveries. Minerals formerly supposed to be rare are now found abundantly, and through the recent developments of chemical industry even such unusual species as samarskite, monazite, and zircon have acquired commercial importance. For example, in response to an industrial demand, North Carolina has supplied zircon and monazite by the ton, and samarskite by the hundredweight; and the output can be increased almost indefinitely. The State has also contributed to science several new species as yet not found elsewhere, and some of these, notably among the vermiculites, are significant for the light which they shed upon other associated minerals.

In the former edition of this report due credit was given to several industrious workers whose enthusiasm had done much for the completeness of the record. The late Prof. J. T. Humphreys, and Dr. C. L. Hunter, Mr. J. A. D. Stephenson, and Mr. G. B. Hanna were there especially named. Mr. William Earl Hidden, of Newark, New Jersey, was also mentioned, but since then his continued labors have added largely to our knowledge of the mineralogy of the State. Mr. G. F. Kunz, also, in a number of separate papers and in his large work upon "The Gems and Precious Stones of North America," has done excellent service to the mineralogy of North Carolina. To Prof. J. A. Holmes, of Chapel Hill, Michigan, much credit is also due, particularly for perfecting the list of localities.

[1] In an earlier form it appeared in 1871 as Appendix C of W. C. Kerr's report. A new edition was printed in 1875 as chap. I of vol. II of the Geology of North Carolina.

In the present memoir there will be found many new analyses, the greater number having been made by the author or under his direct supervision. Several very important analyses, however, were furnished by the chemists of the United States Geological Survey. To the field geologist or the collector of minerals the table of localities at the end of the report will be of especial value.

THE MINERALS OF NORTH CAROLINA.

By Frederick A. Genth.

NATIVE ELEMENTS.

GOLD.

Gold occurs in numerous localities throughout the State, generally in quartz veins of gneissic, granitic, and dioritic rocks, also in those of talcose, chloritic, and argillaceous slates, and in beds of the slates themselves, and in gravel deposits, the débris of the decomposed rocks and veins. The principal counties in which it has been found in sufficient quantity for exploitation are Franklin, Nash, Granville, Alamance, Chatham, Moore, Guilford, Davidson, Randolph, Montgomery, Stanly, Union, Cabarrus, Rowan, Mecklenburgh, Lincoln, Gaston, Catawba, Caldwell, Burke, McDowell, Rutherford, Polk, Cleveland, Cherokee, Jackson, Transylvania, and Watauga.

It is generally more or less alloyed with silver, varying from pure gold on the one side to pure silver on the other. Near the surface it is usually associated with limonite and at a greater depth of the deposits with pyrite, chalcopyrite, galenite, zinc blende, tetradymite, arsenopyrite, rarely with altaite and nagyagite. Specimens of gold, remarkable for their size, have been found at the Reid mine in Cabarrus County, the Crump mine and the Swift Island mine in Montgomery County (at the latter place in plates, covered with octahedral crystals), at the Cansler & Shuford mine in Gaston County, the Little John mine in Caldwell County, and Pax Hill in Burke County. Very beautiful arborescent gold has been obtained from the Shemwell vein in Rutherford County. The variety "electrum," containing from 36 to 40 per cent of silver, has been met with in octahedral crystals at Ward's mine, in Davidson County; also, in Union County, at the Pewter mine, and associated with galenite and zinc blende at the Stewart and Lemmond mines, and in the neighborhood of Gold Hill, Rowan County.

According to the late Dr. Asbury, very interesting specimens have been found at Silver Hill, when the mine was first opened, consisting of lumps of several inches in length, one end of which was pure gold, while the other was pure silver. None of them have been preserved.

SILVER.

Silver is, on the whole, rare in North Carolina. It has been obtained in considerable quantities at Silver Hill, in its native state, foliated and in plates in cerussite, also associated with argentite, galenite and zinc blende in small lumps, and arborescent and filiform masses; it has also been found in small plates and reticulated masses, associated with tetrahedrite and zinc blende, at the McMakin mine, in Cabarrus County; two specimens of laminated silver have been observed by Dr. Asbury at the Asbury mine, in Gaston County; it has also been found by Hon. C. J. Cowles, of the Charlotte Assay Office, associated with chalcocite, at Gap Creek mine, Ashe County, and rarely with the gold ores of Scott's Hill, Burke County.

PLATINUM.

The occurrence of grains of platinum among the sands of the gold-washings of Rutherford and Burke Counties was first brought to notice by General Clingman, who sent half a dozen grains from a mine near Jeanestown to Prof. C. U. Shepard. It has also been found on Brown Mountain, in Burke, northwest of Morganton, on Gen. R. F. Hoke's land. It is reported as having been found near Burnsville, Yancey County. Hidden, after much searching, failed to discover platinum at any of the reported localities.

PALLADIUM.

General Clingman sent a specimen to Prof. C. U. Shepard, which came probably from Burke or Rutherford County, which the latter pronounced "native palladium." Very doubtful.

COPPER.

Copper is found in small quantities in several mines, principally near the surface, in minute distorted crystals with limonite at the McCulloch mine, in Guilford County; arborescent and in crystalline plates at the Union Copper mine, in Cabarrus County, near Gold Hill. One lump of copper, about two inches in size, much resembling that from the Cliff mine, Lake Superior, said to have been found in Stokes County, is in the museum at Raleigh. It also occurs in quartz and epidote rock at Harris Mountain, one-half mile east of Gillis mine, Person County, at Wolf Creek mine, Jackson County, and Ore Knob, Ashe County. A very interesting association is that of native copper in quartz crystals from lower Mecklenburg County, as observed by Mr. E. Bissell.

IRON.

Terrestrial native iron has been found by Mr. W. F. Page associated with monazite, zircon, etc., in the auriferous gravel of Burke County. It was in the form of small malleable grains of almost pure iron, with *mere traces of cobalt*. Apart from this, a great number of highly in-

teresting meteoric masses have been found in the State. Many of them have been preserved through the industrious perseverance of Gen. Clingman, and were described by Prof. Shepard. The meteorites found were both irons and stones. They are:

1. The Caswell County iron, which fell on January 30, 1810; it weighed 3 pounds, and was described by Madison.

2. The Guilford County iron was found in 1820; weighed 28 pounds, and was described by C. U. Shepard in 1841. Analysis gave:

Iron	92·750
Nickel	3·145
Iron sulphide	0·750

3. The Randolph County iron was found in 1822, and weighed about 2 pounds. It was described by C. U. Shepard. It is highly crystalline, distinctly foliated, and presents thin, much interlaced laminæ. When polished and etched it shows very fine almost invisible feathery lines, much resembling hoar frost on a window pane. It is, according to Shepard, pure iron with cobalt only in traces. It has a hardness like the best tempered steel, and a sp. gr. 7·618.

4. The Black Mountain iron, from the head of the Swannanoa River, 15 miles east of Asheville. It weighed 21 ounces and is evidently a fragment from a larger mass. It is highly crystalline, laminated, the laminæ being about one-tenth of an inch in thickness and arranged parallel to octahedral planes. Sulphide of iron being inclosed between the laminæ renders it subject to rapid weathering. The analysis by C. U. Shepard gave:

Iron	96·04
Nickel, with trace of cobalt	2·52
Insoluble sulphur and loss	1·44

Sp. gr., 7·261.

It was discovered in 1835.

5. The Asheville iron, discovered in 1839 on Col. Baird's plantation, near the French Broad River, 6 miles north of Asheville. It weighed about 30 pounds. Analysis by C. U. Shepard:

Iron	96·5
Nickel	2·6
Silicon	0·5
Chlorine	0·2
	99·8

With traces of chromium, sulphur, cobalt, and arsenic.

6. The Buncombe County iron, found in 1845 and described by C. U. Shepard in 1846, weighed about 27 pounds.

7. The Hominy Creek iron, near the base of Pisgah Mountain, 10 miles west of Asheville. It weighed between 5 and 6 pounds. It is vesicular near the surface, and is said to contain chrysolite, and becomes more compact towards the central portion. The polished and etched portions of the compact meteorite show most delicate Widmannstädtian

figures, consisting of very minute and thickly interspersed triangles. Sp. gr. 7·32. The analysis by Clark gave:

Iron	93·225
Nickel (cobalt)	0·236
Iron, nickel, phosphorus, and graphite	4·765
Copper and tin	0·099
Sulphur	0·543
Silicon	0·501
Magnesium, manganese	traces.
	99·369

8. The Madison County iron, from Jewel Hill. Several masses have been found. One of 8 pounds 13 ounces, described by J. L. Smith, was presented to him by Hon. T. L. Clingman, in 1854. It was covered with thick rust, and it deliquesces on account of the presence of ferrous chloride. The etched surface shows the most beautiful fine Widmannstädtian figures.

The analysis by Smith gave:

Iron	91·12
Nickel	7·82
Cobalt	0·43
Phosphorus	0·08
Copper	trace.
	99·45

Another mass, which weighed about 40 pounds, was found in 1857; part of it is in the collection of Amherst College.

Still a third mass, found in 1873, is known to collectors as the Duel Hill iron. It weighed 25 pounds, and shows Widmannstädtian figures with octahedral structure, inclosing bright nickel iron. Deliquesces on account of inclosed ferrous chloride. Sp. gr. 7·46. The analysis by B. S. Burton gave:

Iron	94·24
Nickel	5·17
Cobalt	0·37
Copper	trace.
Insoluble[1]	0·15
	99.93

9. The Haywood County iron, described by Shepard, weighed only one-eighth of an ounce. It is highly crystalline. When polished and etched shows brilliant Widmannstädtian figures. It is also irregularly veined by a black mineral, which appears to be magnetite. Sp. gr. 7·419. Contains iron, nickel, chromium, and phosphorus.

10. The Rockingham County iron, from Smith's Mountain, 2 miles north of Madison; found in 1866 in an old field grown up with pines, but cultivated 10 or 15 years previously. It fell probably in the interval. The original weight was 11 pounds, the greater portion of which is preserved in the museum at Raleigh. It is highly crystalline and on etching

[1] Silica, iron, nickel, chromium, and phosphorus.

gives fine Widmannstädtian figures, showing that it consists of probably three different kinds of iron. Contains also schreibersite in short, very minute quadratic crystals; the so-called rhabdite; and, according to J. L. Smith, *solid* chloride of iron. Sp. gr. 7·78. It has been analyzed by me (I) and J. L. Smith (II) as follows:

		I.	II.
Iron		90·41	90·88
Nickel		8·74	8·08
Cobalt			0·50
Copper		0·11	0·03
Insoluble phosphide	Iron	0·27	.....
	Nickel (cobalt)	0·33	.....
	Phosphorus	0·14	0·03
		100·00	99·46

11. A second mass of iron from near Old Mansion House, on Deep Spring Farm, Rockingham County, now in the State museum at Raleigh, has recently been analyzed by F. P. Venable. Results as follows:

Iron	87·01
Nickel	11·69
Cobalt	0·79
Chlorine	0·39
Phosphorus	0·04
Silica	0·53
	100·45

12. A small meteoric iron, weighing only 428 grammes, was found on Linnville Mountain, in Burke County, about 1882. It came into the possession of Mr. Norman Spang, of Etna, Pennsylvania, from whom it was obtained by Mr. G. F. Kunz, who described it. Its dimensions are 65 mm. long, 35 mm. high, and 38 mm. wide. It is rough on one side, with very shallow pittings on the other; it shows traces of a black crust, and although the mass has not rusted, small drops of ferrous chloride have collected in crevices. It contains some troilite, but does not show the Widmannstädtian figures. A partial analysis was made by W. D. Weikel (I) in 1886, in the laboratory of the University of Pennsylvania; and later a more complete analysis was reported by J. E. Whitfield (II):

	I.	II.
Iron	85·83	84·56
Nickel	13·44	14·95
Cobalt	·73	·33
Copper	undet.	none
Sulphur		·12
Carbon		trace
Phosphorus		trace
Silicon		none
	100·00	99·96

The iron is now with the Kunz collection in the imperial cabinet at Vienna.

13. Another iron from Burke County was found by a plowman about 2 miles from Bridgewater Station, near the McDowell County line. It was broken by some laborers into two pieces, weighing 10½ and 18½ pounds respectively. Traces of crust are still visible upon its surface, which is very much oxidized. The iron is highly octahedral in structure, and between the plates schreibersite is visible. On the etched surface Widmannstädtian figures are shown similar to those on the Cabin Creek and Glorieta meteorites. Sp. gr. of a fragment 6·617. Analysis by F. P. Venable:

Iron	88·90
Nickel	9·94
Cobalt	0·76
Phosphorus	0·35
Chlorine	0·02
	99·97

For the foregoing particulars I am indebted to Mr. G. F. Kunz, the present owner of the meteorite.

14. In the latter part of 1880 a meteoric iron weighing 72 troy ounces was found on a farm near Ellenboro, in Rutherford County. Somewhat over one-half of the mass was given to Mr. S. W. Cramer, of the United States assay office at Charlotte, who recognized its character, and by him a liberal portion was given to the U. S. National Museum. The iron is highly crystalline, and shows Widmannstädtian figures upon its polished surface even before etching. It contains small patches of troilite. From its description by Mr. L. G. Eakins the following analysis is taken:

Iron	88·05
Nickel	10·37
Cobalt	0·68
Copper	0·04
Phosphorus	0·21
Sulphur	0·08
Silicon	0·02
	99·45

15. An iron from Davidson County, identified by Mr. W. E. Hidden, is described by him as follows:

On the 19th of July, 1879, while Mr. Gray W. Harris was prospecting for gold on his plantation near Lick Creek, Davidson County, he found in a ditch a nugget of what appeared to him to be silver. It was covered with a thick, scaly crust of iron oxide; weighed 2¼ pounds; was pear-shaped; measured 4½ by 2½ inches over its broadest surface, and about 1 inch in thickness. Wherever cut or hammered it showed a white metallic mass underlaying the red crust.

This iron has been analyzed by Dr. J. Lawrence Smith and J. B. Mackintosh. I here give the average of four closely agreeing analyses:

Iron	93·00
Nickel	5·74
Cobalt	0·52
Phosphorus	0·36
	99·62

Traces of sulphur, chlorine, and copper; carbon not determined.
This iron does *not* show the customary Widmannstädtian figures.

Apart from the meteoric irons, the following meteoric stones have fallen in North Carolina, and may properly be noted at this point:

16. The Cabarrus County stone fell on October 31, 1849. It weighed 18½ pounds and was an irregularly shaped mass, resembling a truncated four-sided pyramid; on the base a rounded, undulatory surface, coated with a black, coherent crust; tough; color, dark bluish gray, mottled with grains and crystals of lighter color; in structure, subporphyritic. Sp. gr. 3·60–3·66.

According to C. U. Shepard it contains:

Nickeliferous iron (with chrome)	6·320
Sulphide of iron	3·807
Silica	56·168
Ferrous oxide	18·108
Magnesia	10·406
Alumina	1·797
Lime, soda, potash, and loss	3·394
	100·000

17. The Nash County stones fell May 14, 1874, near Castalia. Perhaps a dozen or more stones fell, of which 3 have been found, 1 of over 12 pounds, the others of 2½ and $1\frac{8}{10}$ pounds. They have a dull black coating and consist of darker and lighter portions. Sp. gr. 2·601. The analysis by J. L. Smith shows that it is composed of—

Nickeliferous iron	15·21
Stony mineral	84·79

The nickeliferous iron contains:

Iron	92.12
Nickel	6·20
Cobalt	0·41
Copper and phosphorus not determined.	
	98·73

The stony portion is partly soluble in acids, leaving 47·2 per cent undissolved:

	Insoluble part.	Soluble part.
Silica	52·61	38·01
Alumina	4·80	0·46
Ferrous oxide	13·21	17.51
Magnesia	27·31	41·27
Soda with traces of potash	1·38	.....
Sulphur	.....	1·01
	99·31	98·26

The insoluble portion is mostly bronzite; the soluble, chrysolite, with small particles of anorthite.

18. The Haywood County stone was seen to fall by Mr. W. A. Harrison of Ferguson, about 6 p. m., July 18, 1889, and was picked up hot. It weighed about 8 ounces, and very closely resembled the stones from Mócs, Transylvania. In shape it was slightly oblong, and was covered with a deep black crust, which, broken at one end, showed a perfect chondritic structure, with occasional specks of iron. It was sent to New York to Mr. G. F. Kunz, who furnishes its description; but in December, 1889, it was unfortunately lost.

19. A peculiar substance, consisting principally of iron and silicon, supposed to be of meteoric origin, has been found near Rutherfordton. Shepard described it and called it "ferrosilicine."

In a recent "List and Description of the Meteorites of North Carolina," by Prof. F. P. Venable, published in the "Journal of the Elisha Mitchell Scientific Society," three other occurrences are noted, of which little is known. An iron weighing 56 grammes found in Alexander County in about 1875, is now owned by S. C. H. Bailey, of Oscawana, New York. Another fragment of iron marked as being from Caldwell County is in the State Museum at Raleigh. Also a fragment of a meteoric stone has been reported from Ashe County, but it may be identical with the Grayson County, Virginia, fall.

LEAD.

A few small irregular lumps of what has been alleged to be "native lead" were received from Messrs. Bechtler, of Morganton. They were said to have been dug up 4 miles north of Morganton, in making a road near the Catawba River.

ANTIMONY.

A small piece of native antimony was received from Dr. Hunter. It is quite pure and free from arsenic, but coated with a crust of antimonic oxide. From a small vein in Burke County.

SULPHUR.

It is frequently met with in minute crystals in cellular quartz, filling the cavities, formerly occupied by pyrite, in Cabarrus, Mecklenburg, Gaston, Caldwell, Surry, and Stokes Counties; it also occurs diffused through the interstices of a white quartzose sandrock in Lincoln County.

DIAMOND.

This rare gem has been repeatedly found in North Carolina, and the following occurrences are well established. In every instance it was found associated with gold and zircons, sometimes with monazite and other rare minerals, in gravel beds resulting from gneissic rocks, but it has never been observed in the North Carolina itacolumite or any débris resulting from its disintegration. The first diamond was found in 1843 by Dr. M. F. Stephenson, of Gainesville, Georgia, at the ford of Brindletown Creek. It was an octahedron, valued at about $100. Another from the same neighborhood came into possession of Prof. G. W. Featherstonhaugh, while acting as United States geologist.

The third diamond, at Twitty's Mine, Rutherford County, was observed in 1846 by Gen. Clingman, in D. J. Twitty's collection, and has been described by Prof. Shepard. Its form is a distorted hexoctahedron and its color yellowish.

The fourth came from near Cottage Home, in Lincoln County, where it was discovered in the spring of 1852, and was recognized by Dr. C. L. Hunter. It is greenish and in form similar to the last, but more elongated.

A very beautiful diamond was found in the summer of 1852 in Todd's Branch, Mecklenburg County. It was nearly of the first water and a perfect crystal. It was in possession of the late Dr. Andrews, of Charlotte. Dr. Andrews informed me that a very fine diamond of about the size of a small chinquapin, and of a black color, had been found at the same locality by three persons while washing for gold. In their ignorance, believing that it could not be broken, they smashed it to pieces. Dr. Andrews tested the hardness of a fragment, which scratched corundum with facility, proving it to be a diamond.

A very beautiful octahedral diamond of first water was found many years ago at the Portis Mine, Franklin County. There is a report that a second one has been found at the same locality.

A small diamond was found a few years ago in McDowell County, on the head waters of Muddy Creek.

Dr. C. Leventhorpe, of Patterson, North Carolina, reports that a small, poor diamond was found in a placer mine in Rutherford County a number of years ago; it was given to Prof. C. U. Shepard, who put it in his collection.

G. F. Kunz states that a diamond weighing 4⅛ carats, or 873 mg., was found on the Alfred Bright farm, in Dysortville, McDowell County, in the summer of 1886. *It is quite perfect, but not pure white, having a faint grayish green tint.* In form it is a distorted hexoctahedron with

partial twinning. Its specific gravity is 3·549, and it measures 10mm. in length and 7mm. in width.

According to W. E. Hidden another diamond was found in 1877 by a small boy in the same region as the one above mentioned. It weighed $2\frac{3}{8}$ carats, was shaped very much like a smooth, flat field-bean, and was very well polished naturally. It was white, but somewhat flawed. The crystal planes were very obscure. It was finally sent to New York and cut into a small gem.

GRAPHITE.

Graphite has been found at numerous localities. It forms large beds in the gneissic and micaceous schists. Sometimes very minute scales are disseminated through the gneissic and micaceous, and occasionally the limestone rocks. In most places it is impure and gritty, at others purer and better varieties have been obtained. The largest beds occur in Wake County, others in Lincoln, Cleveland, Catawba, Alexander, Stokes, Surry, Wilkes, Person, Alleghany, Johnston, and Yancey Counties.

SULPHIDES, ETC.

SULPHIDES AND TELLURIDES OF METALS OF THE SULPHUR AND ARSENIC GROUPS.

STIBNITE.

Found in the northern part of Granville County, on the land of Maj. N. A. Gregory.

BISMUTHINITE.

In very minute crystals and specks in chloritic slate associated with gold, chalcopyrite, and pyrite at the Barnhardt vein of Gold Hill, Rowan County.

TETRADYMITE.

This rare mineral has been found associated with gold in quartz at David Beck's mine, 5 miles west of Silver Hill, and at the Allen mine, in Davidson County; also, in minute scales in Cabarrus County, at the Phœnix mine, Boger mine, Cullen's mine, at the Asbury vein in Gaston County, at Capt. Mills's mine in Burke County, and Capt. Kirksey's, McDowell County.

I have analyzed the tetradymite from Davidson County and that from the Phœnix mine, Cabarrus County; after deducting quartz and gold found:

	Davidson County.	Phœnix mine.
Tellurium	33·84	36·28
Sulphur	5·27	5·01
Selenium	trace	.....
Bismuth	61·35	57·70
Copper	.....	0·21
Iron	.....	0·54
	100 46	99·94

MOLYBDENITE.

In granite and quartz veins, in fine scales in the neighborhood of the Pioneer Mills mine, Cabarrus County; also, in Guilford County, and at Peach Bottom mine, Alleghany County; at Haskett's, Macon County; and in many other places west of the Blue Ridge.

SULPHIDES, ETC., OF METALS OF THE IRON, GOLD, AND TIN GROUPS.

ARGENTITE.

In small grains, associated with native silver, in the ores of Silver Hill, Davidson County, and the McMakin mine, in Cabarrus County; also in slates of Montgomery County. (Emmons.) Found also at the Cheek mine, Moore County, at Higdon's mine, in the Cowee Mountains, and in Swain County.

GALENITE.

At Silver Hill sometimes, in highly argentiferous, crystalline, bluish gray masses, also coarsely and finely granular. In coarse-grained masses at the Hoover mine and Boss mine, in Randolph County, and the McMakin mine, Cabarrus County; in small quantities at Miller's mine, Baker mine, and Little John mine, in Caldwell County; at Pax Hill, in Burke County; in Alexander County; at Cansler & Shuford mine, the Asbury mine, the King's Mountain mine, the Crowder's Mountain barite mine, and the Oliver mine, in Gaston County; highly auriferous and argentiferous galenite occurs at the Stewart mine, Lemmond mine, Phifer mine, Smart mine, Moore mine, and Crowell mine, and elsewhere in Cabarrus; and at Long mine in Union County; at the Cheek mine, Moore County; with copper ores it is found at the Clegg's and Williams's mines, in Chatham County; the Peach Bottom mine, in Alleghany County; at Marshall, in Madison County; with gold at Murphy, Cherokee County, and in Lincoln, Macon, Swain, and Surry. Specimens of fine-grained galenite have also been obtained from Beech Mountain, in Watauga; on Elk Creek, Wilkes County; and at the Steele mine, Montgomery County.

ALTAITE.

This exceedingly rare mineral occurs associated with gold, nagyagite, galenite, etc., at King's Mountain mine, Gaston County.

BORNITE OR VARIEGATED COPPER ORE.

I have crystalline specimens of bornite from Guilford County, probably from the Gardner Hill mine; it is of somewhat rare occurrence in North Carolina, but has been found with other copper ores at Clegg's mine, in Chatham County; Marshall, in Madison County; Peach Bottom, Alleghany County; the Gap Creek mine, Ashe County; near Concord, Cabarrus County, and at Well's farm in Gaston.

SPHALERITE OR ZINC BLENDE.

This mineral occurs in quantities sufficient for exploitation only at a few mines. The principal localities are Silver Hill and Silver Valley, in Davidson County, and the McMakin mine, in Cabarrus County, where it is found associated with silver ores; associated with gold ores at Stewart, Lemmond, Long, and Moore mines, and rarely at the Union mine, in Union County; in limestone at Dobson's mine, Cedar Cove, McDowell County, and in Macon County; in small quantities with other ores at King's Mountain mine in Gaston County; at Clayton, in Johnston County, near Marshall; in Madison County, and on Uwharie River, Davidson County; at the Steele mine, Montgomery County; at Peach Bottom mine, Alleghany County; Crowder's Mountain, Gaston County; and the Smart mine, Union County.

CHALCOCITE.

This is also a copper ore, but rarely met with in the State. The massive variety has been found at the Ore Knob mine, in Ashe County; also associated with bornite at Gap Creek mine, Ashe County; the Waryhut and Wolf Creek mines, in Jackson County; the Gillis mine, and Mill Creek mine, in Person County; also at the Pioneer Mills mine, in Cabarrus; at A. Nichol's, in Swain; and in Guilford County, as a product of the alteration of other copper ores and rarely with silver ores at Silver Hill.

TROILITE.

Interlaminated with the meteoric iron from the Black Mountain, Buncombe County, and in other meteorites, q. v.

PYRRHOTITE.

Compact pyrrhotite is found at the bottom of the Asbury shaft in Gaston County; also associated with chalcopyrite at the Elk Knob mine, Ashe County, on East Fork and West Fork of Pigeon River, Haywood County, in Transylvania County, near Hickory in Catawba County, at Thorn Mountain mine, Macon County, and in Surry and Wilkes (Trap Hill).

SCHREIBERSITE (RHABDITE).

This mineral, of meteoric origin, has been observed in minute quadratic prisms of great brilliancy in the meteoric iron of Smith's Mountain, Rockingham County, and in less distinct particles in many of the meteoric irons.

PYRITE.

Pyrite is one of the most common minerals of North Carolina. It is not only found in globular and irregularly shaped crystalline masses in many of the marl beds of the eastern counties, but many of the gneissic rocks and slates and the traps contain it in considerable quan-

tities, and besides it is found in almost every mine of the State. In Cleveland and Rutherford it is a common constituent of the feldspathic, slaty gneisses, disseminated in minute grains, and its ready oxidation rapidly disintegrates the rocks, so that during the late war copperas was extensively and cheaply manufactured here by simply breaking and heaping the half decomposed fragments of rock in hoppers, leaching and crystallizing. In the gold mines the associated pyrite is generally auriferous. Cubical crystals occur at Hickory, Catawba County; Asbury mine, Gaston County; Soapstone quarry, 12 miles northeast of Statesville; Silver Hill, Gold Hill, and many other localities. Combinations of cubes and octahedra are found in Clegg's mine, Chatham County, and in the Guilford County gold and copper mines; the pyritohedron, often in combination with cubical and octahedral planes, is found at the Stewart mine, in Union County; Cambridge mine, Guilford County; Long Creek mine, Gaston County; Rudesill mine, Mecklenburg County, etc. Large veins of compact pyrite occur in Gaston County.

CHALCOPYRITE.

This is very abundant, and, indeed, is the only reliable copper ore in North Carolina. It has been found in fine crystals at the Gardener Hill mine, probably also at other copper mines of Guilford County. It is very abundant and largely mined at Ore Knob, Ashe County, and promises to be the ore of all the gold mines, which in depth change into copper mines in Guilford, Cabarrus, and Mecklenburg Counties; also at the Clegg mine, in Chatham County; the Conrad Hill and the Emmons and other mines in Davidson County; Peach Bottom and elsewhere, Alleghany County; and at Gap Creek, Ashe County; Newlin's mine, Alamance County; in Alexander; in the gold mines of Union, Rowan, and Gaston Counties; at Macpelah Church, in Lincoln County; in Granville and Chatham Counties; near Hillsboro; near Chapel Hill, Orange County; near Raleigh, in Wake County; in Surry, Wilkes (Trap Hill), Yadkin, Watauga, and Swain counties; and some of the mica mines of Mitchell County; the copper mines of Macon and Jackson Counties—in more than thirty counties, and hundreds of localities; at many of them it is found associated with other ores.

BARNHARDTITE.

A peculiar and rich copper ore, first noticed on Daniel Barnhardt's land and then at the Pioneer Mills mine, in Cabarrus County. It also occurs at the Cambridge mine, in Guilford County; at the Wilson mine and the McGinn mine, in Mecklenburg County; and at Elk Knob, Watauga County. The true barnhardtite occurs in compact masses—having, on a fresh fracture, a very pale bronze yellow color, but rapidly tarnishing with brownish pinchbeck, also with rose red and purplish colors. That from Barnhardt's land has been analyzed by W. J. Taylor (I), that from Pioneer Mills by me (II) and by P. Keyser (III).

	I.	II.	III.
Copper	47·61	46.69	48 40
Iron	22·23	22·41	21·08
Sulphur	29·40	29·76	30·50
Silver	trace		
	99·24	98·86	99·98

There occurs at the Pioneer Mills, associated with the barnhardtite, another copper ore, which appears to be uniform in composition and does not look like a mixture. It is paler than copper pyrites and contains, according to the analyses of W. J. Taylor (I) and Charles Froebel (II):

	I.	II.
Copper	40·2	40·5
Iron	28·4	28·3
Sulphur	32·9	31·1
	101·5	99·9

MARCASITE.

According to the information received from Dr. Asbury, of Charlotte, this mineral occurs in Iredell County.

LEUCOPYRITE.

It has been observed by the late Dr. Asbury, at the Asbury mine, in Gaston County; in nodular masses almost completely altered into scorodite at Dr. Halyburton's, in Iredell County; and at Drum's farm, on White Plains, Alexander County.

ARSENOPYRITE OR MISPICKEL.

It occurs sparingly in North Carolina, and has been observed in minute crystals, associated with gold ores, at the Lemmond and Stewart mines, Union County, and at the Barringer mine and George Ludwick's mine in Cabarrus County. It has been found by Gen. Clingman in Cleveland County, and by Dr. Asbury, at Ore Knob mine in Ashe County, the Honeycutt vein at Gold Hill, and highly auriferous at the Asbury mine, in Gaston County. It also occurs near Cooke's Gap, Watauga County, in fine crystalline particles, disseminated through siliceous rock; and, according to Hidden, at Brindletown (?).

NAGYAGITE.

This exceedingly rare mineral, which previous to its discovery in North Carolina was known only from Translyvania, in Hungary, occurs sparingly in minute crystals and foliated particles at the King's Mountain mine, where it is associated with altaite, gold, etc.

COVELLITE.

Resulting from the decomposition of chalcopyrite and associated with it, covellite occurs at several of the North Carolina copper mines, for instance at the Phœnix mine, etc., in Guilford County; and in fine scales at the Gillis mine and Mill Creek mine, in Person County.

SULPHARSENIDES, SULPHANTIMONIDES, ETC.

PROUSTITE (?).

Microscopic crystals of a bright aurora red color occur with talc, rhodochrosite, etc., at the McMakin mine. As they are rich in silver they are probably proustite.

AIKINITE OR CUPREOUS COSALITE (?).

A mineral containing sulphur, bismuth, lead, and copper, and therefore probably aikinite or cosalite, has been observed in small particles in quartz associated with chalcopyrite at Col. White's mine, Cabarrus County.

TETRAHEDRITE.

Two varieties of tetrahedrite are found in North Carolina, the highly argentiferous (freibergite), in small compact patches of subconchoidal fracture and a dark gray color, associated with silver, sphalerite, galenite, talc, magnesite, etc., at the McMakin mine, Cabarrus County, and the other in the same county at George Ludwick's mine, 14 miles northeast of Concord, rarely crystallized, but mostly massive and of a dark lead-gray to iron color. It is associated with chalcopyrite, scorodite, arseniosiderite, etc., in a quartz vein.

The tetrahedrite from the McMakin mine has been analyzed by myself (I) and by Mr. J. S. de Benneville (II) in my laboratory. The second sample was very pure, and was collected about twenty years ago, and twenty years after the first.

	I.	II.
Sp. gr.	.....	4·776
Sulphur	25·48	26·55
Antimony	17·76	6·90
Arsenic	11·55	13·49
Copper	30·73	37·45
Iron	1·42	2·05
Zinc	2·53	5·67
Silver	10·53	6 47
Manganese	.....	0·45
	100·00	99·12

There is probably an occasional small admixture of argentiferous tetrahedrite with the minerals associated with the native silver of Silver Hill, as they sometimes give before the blowpipe incrustations of antimony.

COMPOUNDS OF CHLORINE, ETC.

HALITE OR COMMON SALT.

Found in the waters of the Atlantic Ocean, from which it can be obtained by evaporation, and in wells and springs at several points in the Triassic beds, e. g., in Chatham, Orange, and Rockingham Counties.

CERARGYRITE.

In some of the gold ores of Scott's Hill, in Burke County, silver is found after roasting; a specimen, which I had an opportunity to examine, makes it probable that it is present as chloride of silver or cerargyrite.

FERROUS CHLORIDE.

It has been observed in the meteoric irons from Asheville and from Jewel Hill, Madison County, which are wet from the deliquescence of this salt. In the Rockingham County iron it has been found in the solid state.

FLUORINE COMPOUNDS.

FLUORITE.

According to Gen. Clingman, fluorite occurs at Brown Mountain, Burke County; also in Watauga; with barite and hematite below Marshall, Madison County, and at King's Mountain, Gaston County. In pseudomorphs after apatite rarely at Ray's mine, Yancey County.

YTTROCERITE (?).

A few minute, deep violet-blue spots were observed in association with pyrochlore, black tourmaline, orthoclase, quartz, etc., at Ray's mica mine, Hurricane Mountain, Yancey County, which are probably yttrocerite.

OXYGEN COMPOUNDS.

OXIDES.

CUPRITE.

Cuprite or the red oxide of copper occurs near the surface in some of the copper mines. It is rarely found in small cubical crystals at Cullen's mine and in octahedra upon native copper at the Union Company copper mine in Cabarrus County. It has been observed at Clegg's mine, Chat-

ham County; at Silver Hill, at the Harris mine, in Person County; in Caldwell, Lincoln, Alleghany, and Ashe Counties, and upon the gossan of the Waryhut mine, Jackson County. At the McGinn mine, in Mecklenburg County, and several of the Guilford County copper mines, cuprite in acicular and capillary crystals (so-called chalcotrichite) was formerly found in beautiful specimens.

MELACONITE.

It is found occasionally as a black coating or a powder associated with cuprite at the McGinn mine, and with zincblende, etc., sparingly at Silver Hill; also at Cullowhee mine, Jackson County.

CORUNDUM.

One of the most interesting minerals, which occurs in the State of North Carolina in a great many varieties, is corundum. In was first noticed when, in the spring of 1847, a large mass of a dark blue cleavable variety was found 3 miles below Marshall, in Madison County. Gen. Clingman's attention having been called to it, he searched for more, and obtained in 1848 a second piece of about half the size. It has since been found 2½ miles north of Marshall, at Haynie's, associated with margarite and rutile. It was afterward found by Dr. C. L. Hunter, in small quantity, in reddish and bluish masses, sometimes crystallized, at Crowder's Mountain, and afterward at Clubb's Mountain and King's Mountain, Gaston County. About 20 years ago large beds of corundum were discovered by Hiram Crisp, near Franklin, in Macon County, at Culsagee or Corundum Hill. Here it is from 10 to 14 feet thick, embedded in prochlorite, between chrysolite and hornblendic gneiss. The corundum itself presents many varieties. Beautiful hexagonal pyramids with basal and rhombohedral planes and of many shades of color, from almost colorless to yellow and deep red, rarely to green, have been found. Some of the crystals are very large, one, for instance, measured 5 feet 2 inches in length. Usually it occurs massive, often in large cleavage masses, frequently of variable colors; some are red and semitransparent and in small fragments even transparent and form a fair ruby; other specimens of reddish or gray corundum have disseminated through the mass the most beautifully colored azure-blue sapphire. Unfortunately the particles of the red and blue are usually too small to have any value as gems. A very peculiar variety is that consisting of white and blue bands. At this locality corundum is associated with prochlorite, black and greenish black spinel, tourmaline, small quantities of rutile, etc., and where it occurs in the mica schist, with muscovite and margarite.

Other localities in Macon County where corundum is mined are Jacob's and Haskett's mines, on Ellijay Creek, and at Robinson's mine, on Sugartown Fork. It is also found at Houston's mine, and at Moore & Higdon's. At West's mine "ruby" corundum occurs in small, irregular crystals and crystalline masses associated with cyanite.

At the Hogback mine, in Jackson County, corundum associated with muscovite, margarite, and tourmaline is embedded in chlorite. At the hanging wall feldspar with crystals of corundum is met with. A small quantity, not exceeding a few ounces, of corundum has been found near the chrysolite outcrop at Webster, Jackson County, and also on Scott's Creek. At Cullakenee mine, in Clay County, a grayish white and blue corundum is found associated with margarite, zoisite, actinolite, etc., and a red variety, sometimes of a deep ruby color, associated with zoisite, smaragdite, cyanite, and a feldspar.

At Penland's, on Shooting Creek, in Clay County, corundum is found associated with margarite and willcoxite. It also occurs in Cherokee County, on Valley River.

In Haywood County, 2 miles northeast of the Pigeon River, where the Asheville road crosses it near a serpentine outcrop, a small quantity of corundum has been found, also on the west fork of Pigeon. About 2 miles north of this is located the Presley mine, which has furnished the most beautiful specimens of blue and grayish blue corundum largely altered into muscovite and albite.

About 20 miles northeast of this mine, in Madison County, is the Carter mine, which yields a white and pink variety of corundum, both in crystals and laminated masses. It is associated with greenish black spinel and prochlorite. Very rarely crystals of asteriated sapphire, implanted on a micaceous rock, are found at this locality.

Corundum is found also in Mitchell County, near Bakersville, in chrysolite.

In the broad-bladed cyanite of Wilkes County, corundum is met with in small reddish brown particles, and in the cyanite of the Swannanoa Gap, in Buncombe County, blue, bluish, white, and reddish corundum. Also at N. P. Watkins's, in the same county.

It is found in the gravel 2 miles west of Statesville, in Iredell County, associated with cyanite, but rarely imbedded in it. Highly interesting crystals and crystalline masses of grayish white corundum more or less altered into muscovite and tourmaline have lately been found by Mr. J. A. D. Stephenson, at Belt's Bridge, and beautiful hexagonal prisms of a pale brownish corundum, with a partial alteration into soda margarite, at Hendrick's farm near Belt's Bridge, Iredell County.

Above Lock's Bridge, on the south side of the South Yadkin River, red corundum occurs largely altered into greenish fibrous and compact muscovite; at the Chipley Farm and Austin's Farm, 3½ miles above Lock's Bridge, gray corundum partly altered into margarite; at Liberty Hill, 3 miles above Austin's Farm, it is altered into margarite and prochlorite; and at Hunting Creek, north of Statesville, blue corundum is partly altered into the rhaetizite—variety of cyanite.

Crystals of corundum surrounded by fibrolite occur at Shoup's Ford in Burke County, and Hidden reports corundum of three colors,

including the "ruby" variety, from Brindletown. It is also reported from Stokes County. In the neighborhood of Morganton corundum is found in muscovite schist, and in the gravel deposits of Burke, McDowell, and Rutherford Counties small grains and crystals, often partly altered into muscovite, are frequently met with. The granular variety of corundum, "emery," has been observed at Crowder's Mountain and also in the titaniferous iron ore belt near Friendship, Guilford County.

At Brackettstown, McDowell County, massive grayish white corundum has been found, and in Mitchell County, at Plum Tree Creek, well developed crystals of a brownish color. Rarely small remnants of corundum are found in the pyrophyllite slates of Chatham County. The associated minerals of corundum are mostly the result of the alteration of corundum, which latter has furnished the alumina necessary for their formation.

HEMATITE.

Red oxide of iron or hematite is one of the most important iron ores of North Carolina. The compact ore, sometimes more or less mixed with the specular variety, forms large beds in Chatham County, at Evans's and Kelley's ore beds, Ore Hill, Buckhorn, etc.; also in Moore County, 12 miles east of Carthage, in Orange County, at Chapel Hill, 6 miles south of Hillsboro; and at J. Woods's, Knap of Reeds; and in Macon, Swain, Buncombe, and many other counties. Foliated and micaceous hematite occurs at Buckhorn, Ore Hill, 7 miles west of Lockville, in Chatham County; Snow Creek, Stokes County; 4 miles south of Salem, in Forsyth County; at Mount Tirzah, in Person County; near Gudger's, 9 miles below Marshall, on the French Broad River, and near Franklinville, Randolph County, and elsewhere. A very fine variety of slaty hematite with crystals of magnetite is found at Cooke's Gap, Watauga County; and both here and at Richlands, in Caldwell County, and near Fisher's Peak, in Surry County, martite occurs. Other localities are: Smith's River, 2 miles east of Morehead's factory, in Rockingham County; a granular variety 1 mile east of Gaston, at House's mill, Cabarrus County; at Hickory, Catawba County; in Lincoln, Gaston, and Mecklenburg Counties, etc. The ocherous variety has been observed in Buncombe County, 4 or 5 miles west of Asheville, at Valley Town, on Peachtree Creek, Cherokee County, and in a great many gold mines. Hexagonal scales of hematite in crystals of quartz occur at King's mill, Iredell County.

MENACCANITE.

Many of the titaniferous iron ores are mixtures of true magnetite and menaccanite, others belong to this species, and others again are really magnetites, in which a portion of the iron is replaced by titanium. Our present knowledge of these ores is too limited to put all the varieties occurring in the State with certainty in the place where they belong.

Those from the following localities appear to belong under this head: Franklin, in Macon County; Big Laurel, in Madison County; on Ivy, Yancey County; Crab Orchard, Cane Creek, Flat Rock, and Grassy Creek, in Mitchell County; Damascus, Iredell County; Old Harris mine, 12 miles southeast of Charlotte, south end of Crowder's Mountain, and at Wills's, Gaston County; Yadkin River, near Patterson, in Caldwell County, and the neighborhood of Raleigh. Menaccanite in quartz occurs at Fisher Hill, Guilford County. Iserite is frequent in the gold sands of Rutherford, Burke, and McDowell Counties, etc. Menaccanite also occurs at Shoup's Ford, Burke County; at Huffman's, Catawba County; at Culsagee, Macon County; at Haynie's, Madison County, and in Person, Watauga, and Lincoln Counties.

Associated with oligoclase, forming cross fissures in the corundum vein at the Carter's mine occur *two* varieties of menaccanite (ilmenite): (1) of a brownish black color with a somewhat purplish hue, in small masses with indistinct crystalline structure and basal cleavage; (2) in rounded nodules, 1½ to 2 inches in diameter, irregular shape, very fragile, and breaking into small fragments without regular form, and a subconchoidal fracture, resembling the slag-like magnetite from Unkel on the Rhine. Neither variety is magnetic. Mr. Harry F. Keller has analyzed them (I) and (II). I have also analyzed a variety of black, somewhat granular menaccanite (ilmenite) from near Franklin, Macon County (III):

	I.	II.	III.
Sp. gr.	4·67	4·68	.....
Titanic oxide	52·73	52·64	48·61
Ferric oxide	8·08	10·07	9·76
Ferrous oxide	33·08	31·11	40·22
Magnesia	5·33	5·33	1·38
Silica	0·14	.....	.....
	99·36	99·15	100·00

Menaccanite is also named by Hidden among the minerals occurring at Brindletown.

SPINEL.

The only spinel which has been found in North Carolina is that which results from the alteration of corundum, and it is usually a mixture, in variable proportions, of the varieties pleonaste and hercynite, sometimes with an admixture of that called picotite. In the chlorites of the Culsagee mine it is found in octahedral crystals with dodecahedral planes, but usually massive, coarsely to finely granular. Its color is black, but by an incipient alteration on the surface it generally becomes of a peculiar greenish gray color and satin-like luster. Some varieties are blackish green, but so dark that the green can be observed

only in thin splinters; it is rarely found at the Cullakenee mine in Clay County, but frequently met with at the Carter mine in Madison County, where it is mostly of a very dark green color. Several vari ties from the Culsagee mine have been analyzed. (I) A fine grained variety of 3·766 sp. gr., by G. A. Koenig; (II) a coarser grained variety of 3·797 sp. gr., by the same; and (III) the coarse-grained crystallized dark green, of 3·695 sp. gr., by myself. IV is an analysis of a greenish black spinel from the Carter mine, sp. gr. 3·77, made by Mr. J. S. de Benneville in my laboratory. In I, II, and III some mechanical admixtures have been deducted:

	I.	II.	III.	IV.
Alumina	54·32	56·58	66·63	67·54
Chromic oxide	3·96	2·28	trace	.....
Ferric oxide	11·51	9·66	1·80	.....
Ferrous oxide	11·16	14·60	11·35	13·38
Magnesia	19·05	16·88	19·86	18·62
Cupric oxide	.....	.....	0·11	.....
Nickelous oxide	.....	.....	0·25	.....
	100·00	100·00	100·00	99·54

Black octahedral crystals of vitreous luster from the Tibbets mine, in Macon County, are probably pleonaste.

GAHNITE.

Gahnite, or automolite, is mentioned by Gen. Clingman as occurring in Cleveland County; also in Mitchell County, at the Deake mine, where it occurs in small, compact, dark green masses, in part altered into and surrounded by fibrous muscovite.

I have made an examination of it and found:

Copper oxide	0·30
Zinc oxide	38·05
Manganese oxide	0·29
Magnesia	0·79
Ferrous oxide	1·14
Ferric oxide	4·50
Alumina	54·86
	99·93

Sp. gr.. 4·576

MAGNETITE.

This is the most abundant and most valuable iron ore in North Carolina. It occurs in small octahedral crystals in the granite at Dunn's Mountain, in Rowan, and in the granites and gneisses and (especially) the syenites very commonly in many counties, and in the slates at Fisher's Peake and Chestnut Mountain, in Surry County; also at Bull's Head, in Alleghany County, in quartzose sandrock and hematite at Cooke's Gap, Watauga County; at Capp's Hill, in Mecklenburg County;

and Fisher Hill, in Guilford. It occurs in its granular variety, mixed with muscovite, manganiferous garnet, etc., at Buckhorn, in Chatham County, and mixed with menaccanite and occasionally with corundum, in a succession of beds, passing through the gneissic rocks of Davidson, Guilford, Forsyth, and Rockingham Counties. There appear to be several isolated outcrops northwest of this band and between it and the Dan River, and also in Randolph and Montgomery Counties. A band of granular magnetite, free from titanic acid, mixed with actinolite, tremolite, and a little epidote, passes from near Danbury in Stokes County, and also from Surry County, through Yadkin, Forsyth, Davie, Lincoln, and Gaston Counties. It contains some of the most valuable ore beds. It is also found in large beds near Newton, in Catawba County; at Comb's farm, Summer's farm, and Thomas Payne's farm, in Iredell County; also in Orange, Mecklenburg, and Cabarrus Counties. Some very valuable ore beds of crystalline magnetite occur in Swain, Madison, Macon, Haywood, Burke, Alexander, Wilkes, Orange, Mitchell, and other counties, the most extensive probably at Cranberry. A granular ore, similar to the ores of Surry County, has been worked at the north fork of New River, near the mouth of Helton Creek, and on Horse Creek, in Ashe County. There are many other localities in which magnetite occurs, but they are of less importance than those enumerated.

CHROMITE.

Occurs in the chrysolite beds, which form lenticular masses in the hornblende slates, etc.; in minute octahedral crystals and granular masses at Culsagee; also at Higdon's, Ellijay's Creek, and at Moore's mine, in Macon County; near Webster, at Hogback, at Ainslie's, and on Scott's Creek, in Jackson County; on Mining Creek, near Hampton's, in Yancey County; at Cullakenee, in Clay County; Carter's mine, in Madison County; in small quantities near Bakersville, Mitchell County; on South Toe River, on Rich Mountain, Watauga County, and in Ashe County. Where it is found in abundance, it may become a valuable ore when it can be brought to market at a low freight. A small admixture of chromite is found in the titaniferous magnetite belt of Guilford, Rockingham, and other counties. Crystals of chromite are frequently met with in the gold sands of Burke, McDowell, Rutherford, etc.

The analysis which I have made of a compact variety of chromite from near Franklin, Macon County, gave:

Chromic oxide	44·15
Alumina	22·41
Ferric oxide	5·78
Ferrous oxide	11·76
Magnesia	15·67
	99·77

Sp. gr., 4·319.

The pure octahedral crystals of chromite washed out of gravel at Culsagee, Macon County, have been analyzed in my laboratory by Mr. J. S. de Benneville. Sp. gr. 4·79. Deducting 2·70 per cent of silica, the mineral contains:

Chromic oxide	56·60
Alumina	5·31
Ferric oxide	10·98
Ferrous oxide	19·91
Magnesia	7·20
	100·00

CASSITERITE.

Found in 1882, near King's Mountain, Gaston County, by Mr. R. T. Claywell. It was first recognized as cassiterite by Hidden, and the mineral was afterward more fully investigated by Prof. C. W. Dabney, jr. It generally occurs in irregular cryptocrystalline and massive lumps of a dark brown color, but also in many shades from colorless to black. The largest piece yet found weighed about 14 ounces. Specific gravity, 6·6 to 6·9. According to Hidden, the ore is sparsely disseminated over a very considerable area in and about King's Mountain Village, but no paying deposits have yet been discovered. Analyses by Dr. Dabney gave for two varieties:

	Light grayish.	Dark brown.
Stannic oxide	94·70	82·99
Tungstic oxide	0·92	1·14
Sulphur	trace	0·46
Arsenic	trace	trace
Iron and manganese oxides	undet	undet
Silica	1·76	2·36
	97·38	86·95
Metallic tin	74·41	65·21

URANINITE.

It was found by Prof. Kerr at the Flat Rock mine, Mitchell County, in 1877, in small nodules of gummite and uranotil, forming the nucleus of these minerals, both of which are resulting from its decomposition. It has since been found at one or two other mines in Mitchell, especially at the Deake mine, in cubes and cubo-octahedrons, of sp. gr. 8·968 to 9·218; color, iron-black to brownish, according to the extent of the alteration. The uraninite from the Flat Rock mine has lately been

analyzed by W. F. Hillebrand in the laboratory of the U. S. Geological Survey, as follows:

Uranic oxide	50·83
Uranous oxide	39·31
Thoria	2·78
Cerous oxide	0·26
Lanthana and didymia	0·50
Erbia and yttria	0·20
Lead oxide	4·20
Ferrous oxide	trace
Lime	0·85
Magnesia and alkalies	0·30
Water	1·21
Silica	0·03
Phosphoric acid	?
Nitrogen	0·37
Insoluble	0·10
	100·99

Sp. gr., 9·086.

The material, which was received from Mr. W. E. Hidden, was slightly altered, containing minute crevices filled with gummite.

RUTILE.

In beautiful crystals at Crowder's and Clubb's Mountains, Gaston County; also granular at the same localities; rarely in small grains or crystals with the corundum of the Culsagee mine in Macon County and the Hogback mine in Jackson County; in acicular crystals, sometimes over 1 inch in length, near Beattie's Ford, Mecklenburg County; in long crystals in quartz on a hill near Buckhorn Falls, in Chatham County, at the head of Cane Creek, Mitchell County; in beautiful acicular crystals at Mrs. Daniel's farm near Mount Pisgah, at Mrs. Jordan's near King's mill, at Alex. Lackley's, Misses Bennett's, Thomas Adams's, and Mrs. Smith's farm, all in Iredell County; acicular crystals in limonite and quartz on John Lackey's farm near Liberty Church, and Wilson's near Poplar Springs; geniculated crystals at White Plains, at Crouch's, and at Milholland's mills, all in Alexander County. The first-named locality furnishes the most magnificent crystals, sometimes 3 or 4 inches in length, fully developed, with numerous brilliant planes, often geniculated and transparent, with a beautiful red color. According to Hidden, Alexander County must be credited with having produced the most beautiful rutile crystals known to science. He says:

> Rutile is found there in a similar situation to the gems and quartz crystals, i. e., in open pockets; in fact, it is found intimately associated with and implanted upon the gems, and often preponderates over all the other crystal contents. The particular points of difference over the same product from other regions are their mode of occurrence, beautiful natural polish, and crystallographic features. Their color ranges from jet black to clear ruby red and pale yellow. They range from those of minute *sizes to rare* examples 3 inches long and one-half inch diameter. Their luster in some

cases approaches that of polished steel. Gems have been cut from the most solid crystals and the result compares favorably with the rare black diamonds from Brazil, Only experts could tell them apart.

Curiously jointed, mitered, and reticulated crystals and also masses of crystals thus united have been commonly met with; all of which are found to follow certain arbitary twinning laws and are not accidentally brought together into such strange shapes as a cursory examination might seem to indicate.

This description applies in particular to crystals found in or near the emerald and hiddenite mine. Rutile is also abundant in coarse crystals near Bryson City, Swain County; in acicular crystals in brownish amethyst, at the head of Honey Creek, Wilkes County; in dark, almost black, crystals in Clay County; in quartz in Yancey County; in small grains and crystals in the gold sands of Burke, McDowell, Rutherford, and Polk Counties; acicular crystals in quartz at Dietz's, Van Horn's, and Hildebrand's, and in large crystals also at the latter point, Burke County; in large crystals at E. Balch's, H. Balch's, Widow Balch's, Huffman's, and D. Lutz's, and in amethyst at the last two points—all in Catawba County; in amethyst in Cabarrus near Concord, and in Randolph near Pilot Mountain; penetrating corundum near Bakersville, Mitchell County; at Ray's mine, and elsewhere in Yancey County; in reticulated acicular crystals in the northwest corner of Lincoln County (Hunter).

Under the name of edisonite, Hidden describes a supposed fourth form of titanic oxide from the Whistnant gold mine in Polk County. It has been shown by Mügge to be only a variety of rutile.

ANATASE.

Anatase has been found in small, brilliant, tabular crystals, in the gold sands of Burke County, by myself and Mr. Hidden. The latter also reports it from Alexander County, in quartz, and from McDowell and Rutherford Counties. At Brindletown, in Burke County, the crystals were of unusual size; some were highly modified, and a few were transparent and glassy, and of a pale green or blue color.

BROOKITE.

In the gold sands of Rutherford, McDowell, and Burke Counties, brookite occurs in small, short, slender, rhombic prisms. At Brindletown Hidden found it varying in color from dull yellow to brown, a few crystals being of a fine red with highly modified terminations.

PYROLUSITE.

It is found near Murphy, Cherokee County; also 2 miles north of Hickory, Catawba County, and with silver ores at the McMakin mine, Cabarrus County; also in fine crystalline masses at Beck's ore bank, 3 miles from Ellison's ore bank, Gaston County; near Danbury, Stokes County; near Webster, Jackson County; in Surry County, near Dob-

son; and in Alexander, Swain, and Mitchell. No large deposits have yet been discovered in North Carolina.

BRAUNITE (?).

Found in quartz near Hillsboro, Orange County. K.

HAUSMANNITE (?).

Recently reported from near Dobson, Surry County, by H. C. Lewis; and it also occurs in Chatham. K.

DIASPORE.

Gen. Clingman observed this rare mineral associated with blue corundum from near Marshall, Madison County. I have not been able to distinguish it with certainty from any other of the corundum localities, but it was observed in very minute but beautiful acicular crystals of the usual form in a cavity of massive corundum from Culsagee, by John C. Trautwine, of Philadelphia.

GOETHITE AND LIMONITE.

I put these two species of hydrated sesquioxide of iron together, as without fuller examination it is impossible to distinguish the majority of the specimens. Large beds of hydrated sesquioxide of iron are found at Ore Hill and elsewhere in Chatham County, and in Johnston, 5 miles west and northwest of Smithfield; near the High Shoals, in Gaston County; in Lincoln and Catawba Counties; near Murphy and along Valley River and Notteley, in Cherokee; in Mitchell, Buncombe, Watauga, McDowell, Burke, Caldwell, Alexander, Wilkes, Surry, Haywood, Macon, Henderson, Transylvania, Davidson, Wake, and other counties; and superficial beds of it are also frequently found in the eastern counties—Nash, New Hanover, Pender, Jones, Duplin, etc. Brown hematites accompany in small quantities many of the magnetite and hematite beds, and form the upper part of many of the gold and copper mines; they are often the result of the alteration of siderite and pyrite, and show frequently the form of the original mineral: for instance, at Conrad Hill, in Davidson County; Cabarrus County, Guilford County, Gaston County, and at Beam's farm, near Center Point, Iredell County.

GUMMITE.

Discovered by Prof. Kerr in 1877, at Flat Rock, Mitchell County. Sometimes found in distinct cubical crystals with octahedral planes, usually in amorphous, compact, nodular masses of a faint resinous luster and of shades between reddish yellow and deep orange red. Fracture uneven to subconchoidal. Sp. gr. 4·840. The mean of three analyses which I have made gives its composition as follows:

Silica	4·63
Alumina	0·53
Baryta	0·98
Strontia	0·05
Lime	2·05
Plumbic oxide	5·57
Uranic oxide	75·20
Phosphoric acid	0·12
Water	10·54
	99·77

These analyses show that the so-called gummite is *not* a distinct mineral species but a mechanical mixture, the North Carolina variety being—

	Per cent.
Uranic hydrate	40·10
Uranotil	33·38
Lead uranate	22·66
Barium uranate	4·26
	100·40

Results from the alteration of uraninite. Found also at the Deake and Lewis mines, Mitchell County. A similar mineral is found in small quantity at Buchanan mine, Mitchell County.

The largest mass of gummite with uraninite found in the State weighed 6 pounds 6 ounces. The nodules often contain black uraninite at the center.

PSILOMELANE.

It is often an associate of gold and iron ores in coatings of the quartz at Scott's Hill, Burke County, together with pyrolusite at Beck's ore bank, on the High Shoals, Gaston County, and in botryoidal masses in a vein, said to be 4 feet wide, near Lenoir, in Caldwell County, near Bakersville, at Gillespie's Gap, in Mitchell County, on Cove Creek, and Richmond Creek, Haywood County, and at Buckhorn in Chatham. In Gaston County at the Long Creek mine, on Cross Mountain, Ormond ore bank, etc., a variety occurs, which contains a small quantity of cobalt and nickel. Also found in McDowell and Lincoln Counties.

WAD.

There is often an imperceptible change from pyrolusite into psilomelane and wad, so that, without analysis, it is often difficult to know to which a specimen may belong. The earthy varieties are generally called wad. A brownish black, earthy wad occurs near Murphy, Cherokee County, also near Franklin, in Macon County, and Webster, in Jackson County, at Gillespie Gap, Mitchell, in Burke, Catawba, Surry and Mecklenburg, and at the Ormond ore bank in Gaston County.

SENARMONTITE OR VALENTINITE.

The incrustation upon the native antimony of Burke County, which does not show any crystalline planes, belongs to either one or the other of these species.

BISMITE.

An earthy, greenish yellow and straw yellow mineral has been observed at the King's Mountain mine and the Asbury vein in Gaston County. It is probably bismite.

MOLYBDITE.

Found associated with molybdenite as a yellow, earthy powder, near Pioneer Mills, Cabarrus County.

QUARTZ.

As a constituent of most of the rocks of North Carolina, and the gangue rock of almost every vein, it occurs nearly everywhere throughout the State. Several of its varieties, however, are of more than usual interest. Rock crystal is found in numerous most beautifully modified forms on the farms of the Lackey family and others near Mahoffey's mill, Alexander County. These have been the subject of a highly important crystallographic investigation by Prof. Gerhard vom Rath, of Bonn. Unusually large masses of rock crystal from near Jefferson, Ashe County, were sent to New York in 1887. One perfect crystal weighed 20½ pounds; another crystal weighed 188 pounds, and a third weighed 285 pounds. The last named was 29 inches long, 18 wide, and 13 thick. Some of the masses found would yield perfectly pellucid crystal balls of 5 inches in diameter. This occurrence has been described by G. F. Kunz.

Good doubly terminated crystals occur at Sugar Mountain, Burke County. Rock crystals are also found in Rutherford County; near Morganton, Burke County; near Hickory, Caldwell County; Catawba County, Iredell County; Mountain mine, in Cleveland County; at Hampton's, on Mining Creek, Yancey County; Stokesburg, in Stokes County; Macon County, Swain County, Rich Mountain, head of Cove Creek, in Watauga County; Mitchell and Transylvania, in Wilkes, Guilford, Lincoln, Gaston, Burke, Anson, Granville, Wake, Moore, Warren, and other counties. Quartz crystals, inclosing liquid (hydrolite, Humphreys), in beautiful specimens, are found on Isaac Price's farm, White Plains, Alexander County, also found by Prof. Humphreys, in pockets and drift veins in Catawba County, and in the South Mountains, Burke County, one with a bubble which moves nearly 2 inches, and a group of 13 crystals having 50 bubbles. He also found crystals with the basal plane in Burke, Catawba, and Alexander Counties. At the emerald locality, in Alexander County, some 7 years ago, Mr. Hidden discovered a remarkable "pocket" which yielded over 400 pounds of crystals,

many of them containing water bubbles of unusual size. Nearly all of these were destroyed by freezing, which shattered the crystals to fragments. Rutilated quartz crystals of great beauty are met with at several localities in Randolph, Catawba, Burke, Iredell, and Alexander Counties (enumerated under Rutile). Quartz crystals with scaly crystals of hematite occur at King's Mill, Iredell County. Quartz between laminæ of muscovite, occurs at the Deake mine, on Toe River, Mitchell County. Radiated quartz is found at Dillahay's gold mine, in Person County and in Wake County. Amethyst, in very fine crystals and clusters of crystals, and of a good violet or pink color, but mostly of a dark, smoky color, is found at Randleman's, Lincoln County, also at the lead mine, Alexander County, at Hickory, Catawba County, in Rutherford, Chatham, and Wake Counties; amethyst of a deep purple color with rutile occurs in Catawba County, and a smoky amethyst with rutile, at the head of Honey Creek, Wilkes County. Rose quartz is found at Highlands, in Macon, near Franklinville, in Randolph (with acicular rutile), White Plains, Alexander County, and near Concord, Cabarrus County, likewise penetrated with rutile. Smoky quartz is found 3 miles from Taylorsville, Alexander County, on Cavin's and also on Pritchard's and Patterson's farms; it also occurs in large crystals on Brush Creek, Mitchell County, in the drift of Brindletown, Burke County, at the mouth of Beaver Dam Creek, Cherokee County, and in Alleghany County.

Milky quartz is found at Roseman's farm, Alexander County, at the forks of the Laurel, Madison County, and at War Hill, Surry County; opalescent quartz at Dan River, Stokes County. Quartz pseudomorphous after calcite, both crystallized and fibrous, is found 2 or 3 miles northwest of Rutherfordton, Rutherford County; the irregularly shaped fragments frequently contain water. Similar pseudomorphs occur at Crawford's farm, 5 miles east of Statesville, in Iredell County; and a peculiar variety of pseudomorphous quartz, after feldspar perhaps, occurs at Shooting Creek, Clay County. Concerning the quartz at Crawford's farm, Hidden says:

> From a careful study of the rock in situ and of many specimens from the localities, I am forced to conclude that these forms of quartz are pseudomorphs of the interstices between crystals of some mineral that crystallized in thin, flat, tabular forms.
>
> Sections of these water-bearing forms present an interior of bright transparent crystals, or of mammillary chalcedony, while the structure of the walls is semi-radiated from the exterior. Careful examination of the surfaces shows a series of triangular markings (angles 60°) on all sides. Now these markings are exactly what we would expect by the slow deposition of quartz on the basal pinacoid of a uniaxal crystal (rhombohedral), or of the deposition of quartz from solution in a vein filled up with meshed and netted crystals, which being thin, presented only basal planes for contact surfaces. What the original mineral was is not shown by the specimens The casts of crystal cavities in the larger masses show an unmistakable hexagonal prism with a large development of the basal pinacoid (these two planes identified by striations on the quartz), and this characteristic is persistent.

Chalcedony is found near Franklin, Macon County; near Webster, Jackson County; at Hampton's Mining Creek, Yancey County; at

Martin's limestone quarries, in Stokes County; on Alamance Creek, Alamance County; and in Lincoln, Iredell, and Chatham Counties. Hornstone occurs at Martin's quarry, Stokes County; near Asheville, Buncombe County; in Madison County and Iredell County; and in Montgomery, Randolph, and elsewhere. Drusy quartz is frequently found on the decomposed outcrops of the chrysolite beds in Macon, Jackson, Clay, Buncombe, and Madison Counties. Itacolumite or flexible sandstone forms a stratum in the quartzite at Linville, Burke County; Sauratown Mountains, in Stokes County, and Bending Rock Mountain, in Wilkes County. Fossil wood is abundant in the Triassic beds in Anson County, and near Germanton, in Stokes County; near Cheek's Creek, in Montgomery County, and in Johnston County; and in the quaternary gravels of Halifax, Moore, Cumberland, Wayne, and other counties. Agate is found in many places; at D. Caldwell's, Mecklenburg County; near Harrisburg and near Concord, Cabarrus County; in Granville, Orange, and elsewhere. Jasper occurs banded (red and black) in Person County, in Granville (Knap of Reeds Creek), in Madison County (near Warm Springs and on Shut In Creek), in Moore County, in Wake, and elsewhere.

A peculiar purplish brown variety of quartz from Uwharie, Montgomery County, partially analyzed by me, gave:

Ignition	0·70
Silica	91·53
Ferric oxide	5·16
Magnesia	0·14
Lime	0·66
Undetermined	1·81
	100·00

Sp gr., 2·663.

OPAL.

The only variety of opal which has come to my notice from North Carolina is "hyalite" in bluish white mammilary coatings upon the quartz of gold veins in Cabarrus County, and at the Culsagee mine, Macon County. It is rarely found in beautiful, colorless, and white botryoidal incrustations upon foliated chlorite. A peculiar yellowish to brownish hyalite, incrusting quartz, was collected by F. W. Clarke in 1883, at Foster's mica mine, near Jefferson, Ashe County.

TERNARY OXYGEN COMPOUNDS.

SILICATES.

ANHYDROUS SILICATES.

ENSTATITE.

Forms beds at the corundum mine of Culsagee, in Macon County, in coarsely crystalline masses of a brownish gray, yellowish color; in coarsely granular masses with chrysolite, at Webster, Jackson County;

also in small crystalline particles, disseminated through chrysolite, at Hampton's, Mining Creek, Yancey County, and 2½ miles south of Bakersville, in Mitchell County. Bronzite is found at Bald Creek, Yancey County, and near Kernersville, Forsyth County. I had this mineral from the Culsagee mine analyzed in the laboratory of the University of Pennsylvania by Frank Julian, who found:

Water	1·21
Silica	57·30
Alumina	trace
Ferrous oxide	7·45
Magnesia	34·64
	100·60

PYROXENE.

Black and brownish black, cleavable masses, with magnetite, at Cranberry, Mitchell County, and of pale greenish color, with magnetite, on Ivy River, Madison County, and on Horse Creek, Ashe County; in "traps" at Greensboro, Guilford County; green coccolite, in calcite, 2 or 3 miles from the mouth of Bear Creek, in marble, at Walnut Creek, 1 mile from French Broad River, Madison County, and at Goshen, Macon, County. Dark brownish black and black pyroxene is one of the constant constituents of the numerous "trap" rocks found in North Carolina.

SPODUMENE.

Occurs in Sharpe's Township, in Alexander County. The first crystals obtained were pale yellowish green, and were thought to be diopside. They had been found loose in the surface soil by some children living on a farm near Salem Church, and were shown to Mr. William Earl Hidden by Mr. J. A. D. Stephenson, of Statesville. The former gentleman sent specimens to Dr. J. Lawrence Smith, who, by analysis, proved them to be spodumene. The mineral has since been extensively mined under the direction of Mr. Hidden; and the new emerald green variety of spodumene has received the name of hiddenite. As a gem it ranks equal in beauty and value to the emerald, which latter stone occurs with the hiddenite. In color it ranges from fine emerald green through yellow to nearly white. It occurs almost invariably implanted upon the walls of open pockets, associated with a number of other minerals of considerable beauty. The emerald green variety has been analyzed by Dr. J. L. Smith (I) and myself (II), as follows:

	I.	II.
Sp. gr.	3·14	3·166
Silica	64·5	63·95
Alumina	27·0	26·58
Chromic oxide	.....	0·18
Ferrous oxide	1·9	1·11
Lithia	7·5	6·82
Soda	.....	1·54
Potash	.....	0·07
	100·9	100·25

The sp. gr. of the yellowish hiddenite I found to be 3·177; that of the darkest green variety was determined by Smith to be 3·191 to 3.194.

AMPHIBOLE.

Amphibole is represented in North Carolina by numerous varieties. We find white and gray tremolite associated with talc at Marble Creek and Murphy, Cherokee County; also on the Tennessee Creek, Jackson County, in talc and chrysolite; at Webster, Jackson County; the Whiteside Mountains, Sugartown, 8½ miles from Franklin; at the Culsagee mine, Macon County, 2½ miles south of Bakersville, in Mitchell County; at Hampton's Mining Creek, Yancey County; on Toe River; at the Carter mine, Madison County; gap of Black Mountain, and the southeast slope of Three Top Mountain, in Ashe County. Gray and brownish grammatite occurs near the Tennessee Creek; anthophyllite occurs at Culsagee mine and at Gregory Hill, in Macon County; actinolite has been observed in talc near Belt's Bridge, Iredell County; at Shooting Creek, Clay County; Swannanoa River, near Asheville; and with chrysolite at Webster, Jackson County; Hampton's Mining Creek, in Yancey County, 2½ miles south of Bakersville, Mitchell County; in talcose rocks near Tennessee Creek, on the East Fork of Tuckasege 1½ miles from its mouth, Mecklenburg County; Rich Mountain, Watauga County; Franklin, in Macon County; at Bolejack's limestone quarry, in Stokes County; at Rogers's ore bank, near Danbury, in Stokes County; near Morganton, Burke County; and Ellison's, in Gaston County. Asbestos has been found at Webster, and at the head of Cullowhee Creek, Jackson County; on Sugartown Creek, near Franklin; at the Nantehaleh River, in Macon County; the Brushy Mountains; at Baker mine and on John's River and on King's Creek, Caldwell County; and on Smith's River, Rockingham County, in Franklin and Wilkes Counties; at Hampton's Mining Creek, in Yancey County; at Buchanan's and Cane Creek, near Bakersville, in Mitchell County; also in quartz crystals at J. W. Warren's farm, White Plain's, Alexander County. Black and greenish black hornblende is abundant throughout the State in the hornblende slates, hornblende rocks, syenite, and diorite. It has been found in rather large cleavage pieces 23 miles below Franklin, *on the Swannanoa* River, near Asheville; at the Cullowhee and Savan-

nah mines, in Jackson County; at Jarrett's, on the Nantehaleh, in Cherokee County; and at Polecat Creek and near Greensborough, in Guilford County.

True orthorhombic anthophyllite, well crystallized and transparent, has been described by Penfield from the Jenks corundum mine at Franklin, Macon County. Sp. gr. 3.093. Analysis (Penfield) as follows:

Silica	57·98
Ferrous oxide	10·39
Manganese oxide	0·31
Magnesia	28·69
Lime	0·20
Alumina	0·63
Water	11·67
Loss at 100	0·12
	99·99

SMARAGDITE (?); KOKSCHAROWITE.

A beautiful mineral, which may be a variety of hornblende, occurs at the Cullakenee mine, Clay County. It has a bright color between emerald and grass green, gradually passing into grayish green and greenish gray. Sp. gr. of the grass-green variety, 3·120. It is associated with pink and ruby corundum and a feldspathic mineral. The analysis of the pure material gave Thomas M. Chatard—

Silica	45·14
Alumina	17·59
Chromic oxide	0·79
Ferrous oxide	3·45
Nickelous oxide	0·21
Magnesia	16·69
Lime	12·51
Soda	2·25
Potash	0·36
Ignition (water)	1·34
	100·33

ARFVEDSONITE.

A brownish black or greenish black hornblende-like mineral, is found associated with the andesite, zoisite, and corundum of the Cullowhee mine and Shooting Creek, Clay County, and rarely at Culsagee, Macon County. It is easily fusible and gives a strong yellow flame, and is therefore probably arfvedsonite. An analysis of a black variety by J. L. Smith places it rather under the aluminous hornblende. He found:

Silica	45·90
Alumina	13·34
Ferric oxide	11·46
Lime	12·20
Magnesia	12·53
Soda	3·39
Water	0·66
	99·48

CROCIDOLITE (?)

This mineral I have received from Col. Joseph Willcox, and it is said to come from one of the western counties of North Carolina. The physical properties and the chemical tests which I have made indicate that it is crocidolite. It consists of long, delicate fibers of a blue color, is insoluble in acids, and fuses easily to a black glass, coloring the flame yellow.

BERYL.

Found in six-sided prisms, sometimes doubly terminated, from about half an inch to 4 inches in thickness, and from 1 to 6 inches in length; color yellowish and bluish green, small pieces of the latter color sometimes transparent enough to be cut for gems (aquamarine), associated with orthoclase, muscovite, tourmaline, etc., at Ray's mine, on Hurricane Mountain, Yancey County. Yellowish green crystals have been found at Buchanan mica mine, and elsewhere in Mitchell County. Clear green crystals occur at Balsam Gap mine, Buncombe County. Found also at the Carter mine, Madison County; Thorn Mountain mine, Macon; Casher's Valley, Jackson; on Green River, Henderson County; at E. Balch's, Catawba; Fort Defiance, Caldwell; at Well's, Gaston County. Some very large crystals were found (one 2 feet long and 7 inches in diameter), 4 miles south of Bakersville, and at Grassy Creek mine of still larger size. Green crystals appear at Point Pizzle mine and elsewhere in this county, and on Green River, Henderson County. The most beautiful varieties, similar to occurrences in Siberia, are found in Sharpe's Township, near Salem Church, at White Plains, Alexander County, also in pale green or bluish green modified hexagonal prisms and pale bluish crystals. This is the locality of the emerald and hiddenite mine, and here for 8 years past have been found most magnificent crystals of emerald as regards color, perfection of form, and crystallographic interest. Beryl in yellowish green, hexagonal prisms is also found at Lackey's farm, near Liberty Church, and Isaac Price's farm, White Plains, Alexander County. It also occurs in yellowish green crystals in Catawba County; one bluish green, transparent crystal, implanted in quartz, has been found at Capt. Mills's gold mine, in Burke County, and another of 1 inch diameter and 4 inches length, with a tourmaline crystal of the same length embedded in it. In greenish yellow and deep green crystals, similar to Siberian, in the South Mountains, 9 miles southeast of Morganton, Burke County, and in the Sugar Mountains; also at Shoup's Ford, at Dietz's, Huffman's, and Hildebrand's. In smaller crystals it is found in Jackson County.

I have analyzed a rounded, waterworn, greenish pebble of beryl exhibiting an uncommonly perfect basal cleavage (for this species) from Alexander County, with the following results:

Silica	66·28
Alumina	18.60
Glucina	13·61
Ferrous oxide	0·22
Alkalies	undet.
Ignition	0·83
	99·54

Sp. gr., 2·703.

CHRYSOLITE.

This is one of the most interesting minerals of North Carolina, where it forms large beds between the hornblende and granite rocks. It is unnecessarily called dunyte, from the Dun Mountains in New Zealand, where it occurs under like circumstances. It is generally of a yellowish green color, but also greenish white, gray, and brownish green, mostly finely granular, rarely foliated, occasionally in larger grains disseminated through the fine-grained mass. Associated with chromite, enstatite, actinolite, tremolite, asbestus, talc, chromite, and corundum, at Culsagee mine, near Franklin, Macon County; in Haywood County; near Webster and Hogback, in Jackson County; at Bald Creek and at Hampton's, Jack's Creek, and South Toe River, 7 miles from Burnsville, Yancey County; 2½ miles south of Bakersville, in Mitchell County, at Shooting Creek and Cullakenee mine, Clay County; at Rich Mountain, Watauga County; at the Carter mine, in Madison County; on Ivy, Buncombe County; near the forks of New River, Ashe County; on Little River, Alleghany County; and 4 miles south of Morganton, Burke County. It is also found with bronzite, in hornblende rock, in Guilford County, and near Raleigh, Wake County. I have analyzed two specimens from Webster, Jackson County, one (I) which was finely granular and of a pale greenish color, with a sp. gr., 3·280, the other (II) of a yellowish olive green color, and 3·252 sp. gr., and Thomas M. Chatard one from the Culsagee mine (III):

	I.	II.	III.
Loss by ignition	0·82	0·76	1·72
Chromite	0·58	1·83	.....
Silica	41·89	40·74	41·58
Alumina	trace.	trace.	0·14
Ferrous oxide	7·39	7·26	7·49
Niccolous	0·35	0·39	0·34
Magnesia	49·13	49·18	49·28
Lime	0·06	0·02	0·11
	100·22	100·18	100·66

The chrysolite is subject to extensive alterations, forming serpentine and talc with their usual associates.

GARNET.

Widely distributed through the State, and a constant constituent of many of the mica and hornblende slates, in which it occurs in minute dodecahedral and trapezohedral crystals of a brownish or brownish red color; it also occurs in many of the talcose and chloritic slates; larger trapezohedral crystals of a brownish red color, and sometimes almost black, are frequently met with in the mica mines of Mitchell and Yancey counties; imperfect dodecahedral crystals at Weaver's, Jeanstown, Rutherford County, and in talcose slate, in Rockingham, Cherokee, Madison, Surry, and many other counties. The most beautiful and perfect crystals are large trapezohedra, of a brownish red color, from Burke, Caldwell, and Catawba counties. A very excellent locality is about 8 miles southeast of Morganton, in Burke County, where very bright red crystals are found, some weighing nearly 10 pounds. Several tons of garnet from this locality have been crushed into different grades of fineness and sent to market for the manufacture of "sand-paper."

Another good location is 4 miles from Marshall, where large crystals are found embedded in chlorite slate. Some of these garnets are nearly transparent, and when cut show a peculiar play of colors.

In Alexander County, on Marshall's farm and elsewhere, garnets are found several inches in diameter. Large crystals and crystalline masses of a reddish brown garnet are found near Franklin, Macon County, and on Toe River, Mitchell County. Of good red color it has been observed in the sands from gold washings in Burke, McDowell and Warren counties. The massive manganese garnet or spessartite is abundant at Jeanstown, Rutherford County; at Buckhorn, Chatham County; near Moore's mills, Stokes County; near Gold Hill, in Cabarrus County; near Brevard's forge, 1½ miles from the Vesuvius furnace; near Macpelah church, Lincoln County; near the High Shoals, and at Clubb's Mountain and Crowder's Mountain, Gaston County; near Madison, Rockingham County; near Salem, Forsythe County; on Horse Creek, Ashe County; Linville Mountains and Bridgewater, Burke County; in Guilford County; at Thorn Mountain mine, Macon County; near Marion, McDowell County; at Buchanan mine, Mitchell County; on Pacolet River, Polk County; at Weaver's, Rutherford County, and near Dobson, Surry County.

Mr. G. A. Koenig has analyzed a variety of manganese garnet or spessartite from Yancey County (I), and I that from near Salem, Forsyth County (II), which contain:

	I.	II.
Silicia	35·80	36·74
Alumina	19·06	16·55
Ferric oxide	6·25	undet.
Manganous oxide	28·64	25·80
Ferrous oxide	4·49	14·26
Magnesia	0·60	2·56
Lime	.....	4·09
Sp. gr., 4·14.	99·84	100·00

ZIRCON.

Abundant with the gold sands of Burke, McDowell, Polk, Rutherford, Caldwell, Mecklenburg, Nash, Warren, and other counties, in very minute yellowish brown and brownish white, sometimes amethystine and pink crystals with many planes; large grayish brown crystals of zircons are found so abundant on the south side of the Blue Ridge near Green River, Henderson County, that Gen. Clingman easily obtained in a few weeks in 1869, 1,000 pounds of crystals. More recently, a commercial demand for zircons having arisen, over 30 tons of the mineral have been taken from this region. It is found here embedded in feldspathic gneiss, and also in a similar association at the Jones's mine, near Coleman's station. Found also by Dr. Hunter at Well's farm, Gaston County. It is rarely found at Ray's mine, Hurricane Mountain, Yancey County, and the Flat Rock mine, Mitchell County. It has been observed in dark red brown crystals in the magnetite beds of the Unaka Mountains; an irregular large crystal of about 2 inches in length and a pale brownish gray color has been found by J. A. D. Stephenson near Statesville, Iredell County; and by the same, small crystals embedded in allanite, near Bethany church.

Peculiar dark brown crystals from 1–3mm. in size are found at Low's and Tibbet's mine, in Macon County, which may be zircon. They need fuller investigation. Hidden reports, from the gold sands of Brindletown, good crystals of the variety malacone. The latter are jet black, with occasionally a grayish crust, and are larger than, and of different form from, the zircons directly associated with them. Sp. gr. 4·087. The same authority reports the variety cyrtolite from several places, namely:

Masses and distinct crystals having curved faces and gray brown color have been met with at the Wiseman mica mine in Mitchell County, associated with autunite, fergusonite, and samarskite. Also at Mill's mine, near Brindletown, and at the xenotime and polycrase locality on the Davis land, near Green River, in Henderson County.

With the monazite at Mars Hill, Madison County, zircon crystals of considerable size are sometimes found. One such crystal, sp. gr. 4·507, was analyzed by me as follows:

Loss on ignition	1·20
Silica	31·83
Zirconia	63·42
Ferric oxide	3·23
	99·68

VESUVIANITE.

A mineral resembling vesuvianite occurs in brownish green, indistinct, crystalline masses, intermixed with quartz, and associated with reddish brown garnet, in Macon County.

EPIDOTE.

Epidote is found abundantly in North Carolina, although fine crystals are exceedingly rare. The finest specimen which I have seen, is a crystal, in the cabinet of the University of Pennsylvania, from the gold washings of Rutherford County; it is strongly pleochroic, like the so-called "Puschkinite," from the auriferous sands of Katharinenburg, in the Ural Mountains. Fine crystals have been lately obtained by Hidden, at Hampton's, Yancey County. Yellowish and brownish green crystalline masses, sometimes with indistinct crystals, have been found near White's mill, Gaston County, and near Franklin, in Macon County. At the latter place occurs also a variety in short, stout crystals of a dark brown or greenish brown color (analysis below). In Mitchell County it is found in dark brownish green crystals and radiating masses. Crystals and crystalline masses in quartz at White Plains, Alexander County. Fragments of epidote in greenish crystals, also a granular variety, are frequently met with in the gold sands of Burke, McDowell, and Rutherford Counties.

Epidote of olive green or grayish and brownish green color occurs massive as a frequent admixture of hornblende slate (notably in Mitchell County) or diorite, sometimes forming pure masses of epidosite, as at the foot of Grandfather Mountain, head of Watauga River, Watauga County. It occurs also abundantly and conspicuously, as bright green amygdules in the chloritic amygdaloidal gneisses on Watauga River. It constitutes, with a reddish feldspar, the so-called unakyte rock, which may be seen at Marshall, Madison County, and down the French Broad in occasional seams and thin beds for several miles. It has also been found in many of the magnetic iron ore beds, as at Cranberry, Mitchell County, at Smith's ore bed on Ivy, Madison County, in the beds on Horse Creek, Ashe County, at Buckhorn, Chatham County, etc.

I have analyzed the brown epidote from Macon County, and found the sp. gr. 3·269, and its composition:

Silica	36·95
Alumina	25·82
Ferric oxide	9·97
Ferrous oxide	1·31
Manganous oxide	0·56
Magnesia	0·56
Lime	21·86
Ignition (water)	3·02
	100·08

ALLANITE.

Allanite is found in jet black or brownish black, slender crystals, sometimes of 6 to 12 inches in length, and also in crystalline masses in a granite vein at Balsam Gap, Buncombe County. Also under similar *circumstances* at the Buchanan mine and Wiseman's mine, Mitchell

County, in unusually perfect crystals 2cm. long by 1cm. thick. At the Hiddenite mine it occurs in small, well polished prisms. In massive form it occurs near Bethany church, Iredell County, in large quantities, with small crystals of zircon imbedded in it.

Another promising locality is near Democrat P. O., Madison County. It has also been identified by Hidden among the minerals from Brindletown, and from the Henderson County zircon mines. At some of the localities the allanite undergoes an alteration and changes into a pale brownish or brownish yellow mineral which has not been further examined. A mineral of an orange color from the Buchanan mine, resembling gummite, may be the so-called yttro-gummite; the quantity at hand was too small and impure for analysis, but it contains uranic oxide and some of the rare earths of the cerium or yttrium groups.

I have analyzed the allanite from Balsam Gap (I), and the Hiddenite mine (II); Dr. J. W. Mallet has examined the pitchy black variety from Wiseman's mine (III), and Mr. Harry F. Keller that from Bethany Church (IV). The analyses are as follows:

	I.	II.	III.	IV.
Sp. gr.	3·400	3·005	.....	3·63
Silica	32·79	32·05	39·03	31·685
Alumina	18·16	22·93	14·33	17·330
Ferric oxide	1·64	11·04	7·10	7·052
Ferrous oxide	10·08	.....	5·22	.....
Cerium oxide	6·07	.....	.....	10·110
Didymium oxide, Lanthanum oxide	14·40	14·81	1·53	18·990
Yttrium oxide, Erbium oxide	1·84	0·85	8·20	1·120
Manganese oxide	1·23	1·99	trace.	1·025
Magnesia	0·15	1·28	4·29	0.540
Lime	10·95	9·43	17·47	10·785
Soda	0·33	0·54	.....	0.210
Potash	0·12	0·20	.....	trace.
Water	1·89	3·04	2·78	1·460
	99·75	98.76	99·95	100·307

ZOISITE.

The beautiful variety of zoisite, "thulite," has been found in slender, rose-red crystals in the feldspars at the Flat Rock mine, Mitchell County. At the Cullakenee mine it is found as one of the products of the alteration of corundum. Some of the pink as well as the bluish gray corundum is changed into compact and cleavable columnar masses of zoisite of a grayish, greenish, and brownish white color. G. A. Koenig has analyzed the slightly greenish white cleavable variety (I), which has resulted from the alteration of pink corundum. I have made an analysis

of the white, slightly grayish zoisite (II), containing still nuclei of unaltered bluish gray corundum:

	I.	II.
Sp. gr.	3·286	3·224
Silica	40·70	39·86
Alumina	33·86	33·84
Ferric oxide	0·81	1·62
Manganous oxide	trace.	trace.
Magnesia	0·22	0·18
Lime	24·05	23·82
Soda (trace of lithia)	undet.	0·22
Potash	undet.	0·09
Loss by ignition	0·63	0·78
	100·27	100·41

Some 40 years ago, about half a mile southwest of Silver Hill, while searching for the continuation of the vein, a grayish white, foliated and columnar mineral was found which had the appearance of zoisite. No further examination of it was made, and there is probably no specimen preserved. Dr. Hunter reports zoisite from Alleghany County, and it also occurs in Swain County.

PHLOGOPITE.

Small brownish scales of it have been found in the granular limestone of Bolejack's quarry, near Germantown, and at Martin's quarry on Snow Creek, Stokes County, on Walnut Creek, one mile from the French Broad River, in Madison County, on Valley River, in Cherokee County, and at Judge Pearson's, near the Yadkin River, Yadkin County. It is found also near Coleman's Station, in Henderson County.

BIOTITE.

Biotite is a constituent of many of the granites, gneisses, and mica schists of North Carolina. It is found only in small black or brownish black plates or scales. The localities are too numerous for particular mention. It occurs in large plates and in very regular crystals in the mica mines of Mitchell, Haywood, Yancey and especially Macon, notably at Lytle and Thorn Mountain mines.

MUSCOVITE.

The mica of the gneiss and mica schist is mostly muscovite, hence it is one of the commonest minerals of North Carolina. In a few localities it is found in beautiful crystals, for instance, with magnetite, at Buckhorn, in Chatham County, with quartz, at Hickory, Catawba County, and with pyrite, in Stokes County. The most remarkable crystals of muscovite are associated with the minerals of the Emerald and Hiddenite mine in Alexander County. They are hexagonal plates implanted edgewise on the walls of pockets, and are dusted over with a *chloritic* coating, possibly of hisingerite (q. v.), which gives the mica

a peculiar bronzy appearance. An analysis by F. W. Clarke is given below.

Since the year 1868 mica has been mined in many places and has been obtained in large plates, at times over 3 feet in diameter, generally of a brownish color, in masses or large crystals, associated with gray, smoky, or yellowish brown quartz, orthoclase, albite, etc., in numerous localities in Macon, Jackson, Haywood, Buncombe, Ashe, McDowell, Mitchell, Yancey, Alexander, Cleveland, and other counties. A pink colored muscovite in fine scales, much resembling lepidolite, for which it was mistaken, occurs with mica at Ray's, mine in Yancey County, and at the Flat Rock mine in Mitchell County.

A compact variety of this species, often in very fine cryptocrystalline scales or fibrous, radiating masses, frequently resulting from the alteration of corundum and other minerals, was formerly, under the impression that it was distinct hydrous mineral, designated as damourite.

Very fine white and yellowish white pearly scales are found with the cyanite at Crowder's and Clubb's mountains, which result from alteration of the cyanite. Under similar circumstances it is found in Yancey, Cherokee, and Iredell counties. A slaty variety, much resembling the pyrophyllite slates of Chatham and Moore Counties, occurs near Warm Springs, Madison County. The most interesting occurrence of muscovite is that resulting from the alteration of corundum. In this connection it is found in many varieties. It is sometimes in compact masses, with a crystalline structure and a yellowish white color, surrounding the corundum as at the Haskett mine, Macon County, or it envelops the nodules of corundum, as at Belt's Bridge, Iredell County, and has a very fine fibrous structure with delicate silky luster, the fine particles gradually assuming a scaly structure and large size. At Crowder's and Clubb's mountains and Culsagee mine, Macon County, the muscovite, surrounding corundum, occurs in the form of small silver white scales, usually discolored by a thin coating of oxide of iron. At the Hogback mine, in Jackson, and especially in Haywood County, it occurs in a similar manner, but it frequently surrounds large masses of corundum with a compact or semi-fibrous coating with silky luster, which towards the margin becomes more crystalline and scaly; at the Presley mine, Haywood County, it is found in very fine scales, gradually increasing to plates of an inch in diameter, and sometimes directly into large hexagonal crystals of 3 to 4 inches in diameter, still inclosing nuclei of the original mineral.

The following have been analyzed in the laboratory of the University of Pennsylvania, I to IV:

I. The finely fibrous from Belt's Bridge, by Miss Mary T. Lewis.

II. The fine scales from Crowder's Mountain, by Thos. M. Chatard.

III. The fine scales from Culsagee, by Geo. A. Koenig.

IV. Plates of about 1 inch in diameter from the Presley mine, by myself.

V. Carefully purified crystals from the Emerald and Hiddenite mine, analyzed by F. W. Clarke in the laboratory of the U. S. Geological Survey.

The following are the results:

	I.	II.	III.	IV.	V.
Sp. gr.	.....	2·860	2·867	.....	.....
Silica	45·96	43·51	45·02	44·89	45·40
Titanic oxide	.....	.....	.....	.....	1·10
Alumina	38·22	37·85	35·93	38·02	33·66
Ferric oxide	0.61		2·93	1·96	2·36
Magnesia	.....	0·31	0·34	0·14	1·86
Lime	0·37	0·42	trace.	0·30	.....
Lithia	.....	trace.	trace.	.....	trace.
Soda	0·74	1·04	0·71	0·60	1.41
Potash	9·21	11·35	9·40	10·26	8·33
Fluorine	.....	.....	.....	.....	0.69
Ignition	4·89	7·73	4·93	4·50	5·46
	100·00	102·21	99·86	100·67	100·27
Less oxygen	.....	.....	.....	.....	0·29
					99·98

The soft, pseudomorphous crystals in the form of staurolite from Cherokee County are probably muscovite.

LABRADORITE.

A white, and in some portions colorless, very lustrous, cleavable variety with very few triclinic striæ, occurs at the Cullakenee mine, in Clay County. It has a sp. gr. of 2·62. I had it analyzed in the laboratory of the University of Pennsylvania by Mr. W. H. Jarden, who found:

Silica	55·61
Alumina	26·90
Lime	9·60
Soda	6·97
Potash	0·55
Ignition (water)	0·35
	99·98

It has been found in gray, granular, cleavable masses, but only at a few localities.

Near the road, 6 miles north of Burnsville, in Yancey County, it is associated with mica, garnet, etc., as one of the constituents of a stratified rock; it occurs in a trap near the Tuckasegee Ford, half a mile from the Catawba River, on the road to Charlotte, in Mecklenburg County; also at Shiloh Church in Granville County, and in large crystals in the heavy trap on Toe River below Bakersville, Mitchell County. The latter locality furnishes specimens which show slightly the play of bluish colors. It is one of the constituents of the cryptocrystalline trap-rock found throughout the State.

ANDESITE.

In snow white and bluish white, cleavable masses, showing fine striæ upon the cleavage planes, associated with black hornblende or arfvedsonite at the Cullakenee mine, Clay County; and from the same locality as a very fine-grained, white feldspar associated with zoisite and margarite, and like the latter, resulting from the alteration of corundum. Both have been analyzed—the first by G. A. Koenig (I), the latter by T. M. Chatard (II):

	I.	II.
Sp. gr.	2·611	2·610
Silica	57·29	58·41
Alumina	26·52	25·93
Ferric oxide	0·21	0·38
Magnesia	0·15	0·18
Lime	7·80	5·82
Soda	6·75	6·45
Potash	0·33	2·10
Loss by ignition	1·43	0·93
	100·48	110·20

There are similar white feldspars at the Hogback mine in Jackson County, and at the Culsagee mine in Macon County, which may belong here. No others have been analyzed.

OLIGOCLASE.

A fine-grained, grayish white feldspar, through which minute particles of black tourmaline are disseminated, occurs in considerable quantities at Culsagee, Macon County, and at the Carter mine, in Madison County. In 1887, at the Hawk mica mine near Bakersville, a peculiar transparent oligoclase was discovered. It was of a faint greenish tint, and clear enough to cut small gems; in fact, it resembled glass more than it did feldspar, especially as it contained stellate tufts of microliths. Analyses as follows:

I. From Culsagee, by J. L. Smith.
II. From Culsagee, by Harry M. Keller.
III. From Bakersville, by F. W. Clarke.
IV. From Bakersville, by E. S. Sperry.

	I.	II.	III.	IV.
Silica	64·12	63·32	62·92	62.60
Alumina	24·20	25·19	25·32	23·52
Ferric oxide	0·14	.....	trace	0·08
Manganese oxide	.....	.....	trace	.....
Lime	2·80	5·01	4·03	4·47
Soda	9·28	8·02	6·18	8·62
Potash	.....	0·25	0·96	0·56
Ignition	.....	.....	0·25	0·10
	100·54	101·79	99·66	99·95

Sp. gr. of the Bakersville mineral, 2·651.

A beautiful variety of "sunstone" oligoclase has been found by Mr. J. A. D. Stephenson near Statesville, Iredell County, associated with yellowish white titanite.

ALBITE.

It is found in large, cleavable masses of a white color, at Point Piz zle, Mitchell County, showing upon the cleavage planes more or less distinct striation. I had it analyzed in the laboratory of the University of Pennsylvania by Frank Julian (I), (see below). Sp. gr. 2·638. There are probably many of the white and grayish or brownish white striated feldspars from mica mines, such as from the Gibbs mine, South Toe River, Yancey County; the Flat Rock mine and the Buchanan mine, in Mitchell County; Ainslie's, in Jackson County; and Thorn Mountain mine, in Macon; and many others, which belong to this species or to oligoclase, which can be distinguished only by analysis. An interesting occurrence is that at the Presley mine, Haywood County, where it, together with muscovite, results from the alteration of corundum. Small white granular cleavable albite, and also compact masses, have been found at the Steele mine, Montgomery County, associated with prochlorite, gold, pyrite, sphalerite, etc. Finely crystallized at the Emerald mine, in Alexander County.

Some of the granitic rocks 3 miles west of Leasburg, Caswell County, contain small grains of a triclinic feldspar, which may be albite.

The compact grayish white variety from the Steele mine has been analyzed by Geo. J. Popplein (II):

	I.	II.
Silica	67·51	60·29
Alumina	20·46	19·66
Ferric oxide	trace	4·63
Manganese oxide	.....	trace
Magnesia	0·34	0·23
Lime	3·08	1·83
Soda	9·15	9·90
Potash	trace	1·71
Loss by ignition	.....	1·20
	100·54	99·45

ORTHOCLASE.

This is one of the most widely distributed minerals in the State, forming an essential constituent of all the granite, gneiss, etc. It is found in beautiful crystals in a band of porphyritic granite, near Salisbury, Rowan County; the High Shoals and White's mill, in Gaston County; and on Hitchcock's Creek, and elsewhere in Richmond County; also in the "chesterlite" form at Silver Hill, associated with pyromorphite and quartz. Cleavable masses of orthoclase are found

at Houp's farm, near Statesville, and near Belt's Bridge, Iredell County. A peculiar variety with satiny luster upon the cleavage planes occurs in Clay County, near Cullakenee. Large lamellar masses of a white, grayish or reddish color occur at Ray's mine, Yancey County; at Flat Rock, Blalock's, and near Bakersville, in Mitchell County; also in Caldwell County; at Hampton's Mining Creek, near Burnsville, Yancey County; on Sugartown Turnpike, 10 miles from Franklin; at the Whiteside Mountain, in Macon County; on French Broad River, in Madison County; and in the mica mines everywhere. The Burnet mica mine, Buncombe County, furnished the museum with a crystal weighing 800 pounds. The peculiar compact variety of orthoclase which is spotted with hydrated sesquioxide of manganese, the so-called "leopardite," is found near Charlotte, Mecklenburg County, and also in Gaston County. It is a variety of porphyry with crystals of quartz disseminated in it. I have made an analysis of the feldspathic constituent, which has a yellowish white color and a cryptocrystalline structure (I). Miss Mary T. Lewis has analyzed in the laboratory of the University of Pennsylvania the orthoclase from Houp's farm, Iredell County (II).

	I.	II.
Silica	75·92	64·56
Alumina	14·47	20·60
Ferric oxide	0·88	
Magnesia	0·09	.....
Lime	0·02	0·36
Soda	4·98	trace.
Potash	4·01	14·85
	100·01	100·37

TOURMALINE.

The tourmalines, found in many localities in North Carolina, are mostly of the black variety. A small, well terminated, transparent green crystal was found by Col. Mills on Silver Creek, Burke County; also a black crystal 4 inches long, embedded in a green beryl crystal. Crystals of from 1 to 2 inches in size have been found near Mountain mine, Cleveland County; on Upper Little River, Caldwell County; at Hanging Dog Creek, in Cherokee; and in Rutherford, Mecklenburg, Yancey, Mitchell, Macon, Haywood, Transylvania, Polk, Buncombe, Caldwell, Stokes, Johnston, Wake, Granville, and other counties. In beautiful, well terminated crystals of 2 to 3 inches in length it is found in the South Mountains 16 miles southeast of Morganton, in Burke County; also near King's mill, Iredell County; and at Warren's, near Salem Church; and at John Lackey's and Isaac Price's, on the White Plains, Alexander County. In slender black crystals, often radiating and needle-shaped, frequently flattened between the plates of muscovite, it is

found at Ray's mine, near Burnsville, where also a greenish and yellowish green, fibrous, and finely columnar variety occurs. It is frequently and in large masses associated with the corundum of Culsagee mine, in Macon County. At the Cullakenee mine, Clay County, it is found in small quantity; also at the Hogback mine, Jackson County, and with the corundum and muscovite at Belt's Bridge, in Iredell County. A large outcrop of fibrous and granular tourmaline, with quartz, is found about two hundred yards northeast of the Ellison mine, on the High Shoals property, in Gaston County, and a peculiar finely striated variety, with quartz, at Clubb's Mountain; similar finely fibrous, woodlike masses occur at Leasburg, Caswell County, and in Wake. It has also been observed in the gold bands from Burke County. Tourmaline rock and slate have been noticed at Kernersville, Guilford County; at Bee Rock, head of Turkey Creek, in McDowell County; at Jeanstown, Rutherford County, 6 miles south of Asheville, on the Hendersonville road, and in Cleveland County.

At the Emerald and Hiddenite mine, in Alexander County, Mr. W. E. Hidden found some brilliant black crystals of tourmaline with fine, polished terminations. An analysis of this tourmaline, made by K. B. Riggs in the laboratory of the U. S. Geological Survey, gave results as follows:

Silica	35·56
Alumina	33·38
Ferrous oxide	8·49
Titanic oxide	0·55
Manganous oxide	0·04
Lime	0·53
Magnesia	5·44
Soda	2·16
Potash	0·24
Water	3·63
Boric oxide	10·40
	100·42

Sp. gr., 3·13.

FIBROLITE.

A reddish white, finely fibrous mineral, with silky luster, from Macon County, probably belongs to this species.

A very interesting occurrence of fibrolite has lately been discovered near Shoup's ford, in Burke County, where it is the result of the alteration of corundum and envelops a core of the original mineral. The fibrolite may, in part, have been changed into muscovite, as it occurs in the micaschist of the neighborhood in small, needle-shaped crystals. A mineral resembling fibrolite is found in quartz in the gold gravel of Burke and McDowell Counties.

CYANITE.

This is one of the characteristic accessories in many of the mica and *horn*blende schists of Macon, Haywood, Transylvania, Yancey, Mitchell,

Caldwell, Catawba, Gaston, and other counties, and is generally of a grayish white or gray color, and in imperfect crystals. Fine crystals occur at Clubb's and Crowder's Mountains, Gaston County; coarsely bladed masses of a blue and greenish color at Swannanoa Gap, Buncombe County; also near Ray's mica mine, on Hurricane Mountain, and elsewhere in Yancey County; Mitchell, Cherokee, and Wilkes counties; six miles east of Danbury, in Stokes County; and near Davidson College, Mecklenburg County. In blue and white bladed crystals in quartz at Hoover's farm, 6 miles southwest of Statesville; also in gravel near Statesville, Iredell County. A grayish white, radiating cyanite is found at Ararat River, 4 miles southeast of Mount Airy, in Surry County, and a white cyanite at the foot of Barnett's Mountain, in Person County. Cyanite also occurs on Valley River, in Cherokee; at Tipton's, in Clay County; in quartz at the head of Jonathan's Creek, in Haywood County; on Bear Creek, in Madison County; at the Buchanan mine, Mitchell County; in the northwest corner of Wake County, and in Moore and elsewhere. At Hunting Creek, north of Statesville, rhetizite in columnar and radiating masses is found, resulting from the alteration of corundum. On Yellow Mountain, near Bakersville, cyanite occurs in very deep blue crystals, equal in color to the finest sapphire. Fine gems have been cut from this mineral.

The white cyanite associated with the lazulite of Clubb's Mountain has been analyzed by Smith and Brush (I); and a brownish white variety from the gravel near Statesville (II) was analyzed by myself:

	I.	II.
Ignition	...	0·38
Silica	37·60	36·85
Alumina	60·40	63·15
Ferric oxide	1·60	trace.
	99·60	100·38

At many localities, notably in Cherokee County, cyanite occurs largely altered into a fine, scaly muscovite.

TOPAZ.

Topaz is reported as occurring at Crowder's Mountain, but it is very doubtful; crystals from there, which were considered topaz, are cyanite. The variety pycnite occurs in finely columnar aggregations of a yellowish and brownish yellow color, associated with garnets, near White's mill, Gaston County.

EUCLASE.

Gen. Clingman mentions a very handsome crystal of this rare mineral from the gold mine of the late Morril Mills, in the eastern part of Polk County.

TITANITE.

Gen. Clingman mentions titanite, or sphene, as occurring in Buncombe County. I have observed it at Morganton Springs, Burke County, in minute brown crystals; in hornblende slate and in granite at White's mills, in Gaston County; at Rogers's ore bank, near Danbury, in Stokes County; and on Hurricane Mountain, Yancey County, To this species probably belongs Prof. Shepard's very doubtful species. pyromelane, from the gold washings of McDowell County. Hidden reports titanite also in Alexander County.

Shepard's xanthitane (q. v.) is an alteration of titanite from Green River, in Henderson County. It often contains unaltered titanite as a nucleus.

I have analyzed a yellowish white titanite which occurs near Statesville, Iredell County, in mica schist, associated with sunstone oligoclase. The crystal was 15mm. broad and 2mm. thick. Sp. gr., 3·477. It contained—

Silica	29·45
Titanic oxide	38·33
Ferric oxide	1·61
Manganous oxide	trace
Magnesia	trace
Lime	29·11
Loss by ignition	0·60
	99·10

STAUROLITE.

Very large, brownish red crystals, from 2½ to 3 inches in length and 1 to 1½ inches wide, single individuals as well as twins, occur at the Parker mine, in Cherokee County. There are many other localities in Cherokee and Macon Counties where it occurs abundantly in argillaceous and talcose slates, as on Persimmon Creek and Hanging Dog Creek; on Bear Creek, Madison County, and Tusquittah Creek, in Clay County. It is found in very small quantity with corundum and chlorite in small, reddish brown grains of vitreous luster, but without distinct form, at the Culsagee mine, Macon County. They have a sp. gr. of 3·711. An analysis which I have made gave—

Silica	27·91
Alumina	52·92
Ferric oxide	6·87
Ferrous oxide	7·80
Magnesia	3·28
Lime and manganous oxide	traces
Ignition (water)	1·59
	100·37

HYDROUS SILICATES.

CHRYSOCOLLA.

Inferior specimens, generally much mixed with other copper ores, *have been observed* at many of the copper mines; for instance, at the

Gardner Hill and Cambridge mines in Guilford County, the Pioneer Mills in Cabarrus County, the Gillis mine and at Mill Creek in Person County, Northington's dam in Harnett County, Wolf Creek mine in Jackson County, at Welch's in Moore County, at Grupy mine and elsewhere in Rowan County, near Elkin in Surry County, the Hopewell in Mecklenburg County, at the Clegg mine and at Snipes' iron mine in Chatham County, Gap Creek mine in Ashe County, and many other places.

CALAMINE.

The only specimen of calamine which I have observed came from Silver Hill, Davidson County, where it occurs sparingly as an incrustation of fibrous and radiating structure upon argentiferous galenite.

TALC.

Resulting from the alteration of chrysolite, foliated talc of a white or greenish white color is found in many of the chrysolite beds west of the Blue Ridge; at Shooting Creek, Clay County; Culsagee, Macon County; Webster, Jackson County; Hampton's, Mining Creek, and Young's, on South Toe River, Yancey County; near Bakersville, Mitchell County, and other localities; in sheets of three-quarters to one inch in thickness and of a somewhat columnar structure near Pilot Mountain, and near Dobson, Surry County; fibrous talc with silky luster and of a white or green color, also compact crystalline white talc with a splintery structure, on Valley River, Cherokee County, and in Macon County. Talcose slate and coarse soapstone are found in many localities throughout the State; it has been noted in some thirty counties: for instance, near Belt's Bridge, Iredell County; in the South Mountains of Burke County; in Caldwell; in Haywood County; near Waynesville; in the north of Wake County, etc. I have analyzed a specimen from Webster, Jackson County (I), and Mr. J. B. Adger has analyzed a compact, faintly greenish variety found 8 miles from the mouth of the Nantahala River (II), as follows:

	I.	II.
Sp. gr.	.....	2·82
Water	·34	6·01
Silica	64·44	57·72
Alumina	·48	2·52
Ferrous oxide	1·39	·64
Nickel oxide	·23	.....
Magnesia	33·19	33·76
	100·07	100·65

PYROPHYLLITE.

In white, yellowish, greenish, and brownish white, stellate aggregations, and in fibrous and radiated masses at Cotton Stone Mountain, Montgomery County; also at Pilot Knob, Randolph County; Davidson College, Mecklenburg County; Hillsboro, Orange County; on Bowlings Mountain, in southern Granville County, in great abundance; Crowder's and Clubb's Mountains, in Gaston County; and on Linville Mountain, McDowell County. The slaty variety forms large beds of yellowish white or greenish color in Chatham, Moore, and Orange Counties.

A schistose imperfectly lamellar variety from the Deep River has been analyzed by Samuel T. Tyson (I), and a similar one, of a somewhat whiter color, from Carbonton, by O. D. Allen (II):

	I.	II.
Sp. gr.	2·92	2·82
Silica	65·93	66·25
Alumina	29·54	27·91
Ferrous oxide		1·08
Water	5·40	5·25
	100·87	100·49

STILPNOMELANE (?).

A mineral, similar to stilpnomelane, has been found in compact greenish black masses at the Cosby mine, Cabarrus County.

GLAUCONITE.

The green grains forming one of the constituents of many of the so-called marl beds in the eastern part of the State are glauconite. It occurs in most of the counties of that section south of Tar River.

SERPENTINE.

The massive varieties are found in many localities. The best appears to come from the neighborhood of Patterson, Caldwell County. It has a dark, greenish black color, contains fine veins of the yellowish green, fibrous and silky chrysotile, and admits of a fine polish; greenish gray, massive serpentine, also with seams of greenish and grayish white chrysotile, is found at the Baker mine in Caldwell County, at which place are also found the varieties marmolite and picrolite; this last also occurs abundantly in the Buck Creek corundum mine, Clay County. Dark green serpentine has been observed in the neighborhood of Asheville in Buncombe County, and in Forsythe and Wake Counties. A grayish or yellowish green serpentine occurs in Caldwell, Wilkes, Surry, Yancey, Stokes, Orange, and Wake Counties, and in the chrysolite *beds of Macon*, Jackson, Yancey, Mitchell, Watauga, Burke, and other

counties; it results from the decomposition of the chrysolite, which, however, is not always complete and gives rise to intermediate stages, in which we have to deal with mixtures of both species. Such a mixture from the Cullakenee mine, Clay County, has been analyzed by me (I), also a compact massive serpentine resembling the variety williamsite, from the chrysolite beds of Webster (II).

The picrolite from Buck Creek has been recently analyzed by Dr. E. A. Schneider, of the Geological Survey (III), who has also analyzed an alleged deweylite from Corundum Hill (IV), which proves to be only serpentine:

	I.	II.	III.	IV.
Silica	35·19	43·87	42·94	41·90
Alumina	0·64	0·31	1·72	0·71
Ferric oxide	.....	.....	3·33	0·91
Ferrous oxide	9·70	7·17	1·88	undet.
Nickel oxide	.....	0·27	0·61	0·10
Manganese oxide	.....	trace	.....	.....
Magnesia	40·99	38·62	36·53	40·16
Lime	.....	0·02	.....	.....
Water	13·48	9·55	13·21	16·16
Chromite	.....	0·57	.....	.....
	100·00	100·38	100·22	99·94

DEWEYLITE.

This mineral is found in all the chrysolite beds of the western counties, in yellowish and greenish masses, in thin veins or seams through the decomposed rocks.

For the supposed deweylite of Corundum Hill see serpentine.

CEROLITE.

In small veins or seams in decomposed chrysolite at Culsagee mine, Macon County, forming white or yellowish masses. It has not been analyzed.

GENTHITE.

In amorphous apple-green coatings upon decomposing chrysolite, at Webster, Jackson County, sparingly at the Culsagee mine, Macon County, and also on Ivy River, Buncombe County.

KAOLINITE.

Snow-white kaolin is found as the result of the decomposition of orthoclase at most of the mica mines in Mitchell, Yancey, Macon, Ashe, and other counties. Good qualities are found 6 or 7 miles from Newton, Catawba County; also in Lincoln, Burke, and many other counties. Clay for firebricks and earthenware occurs in many localities throughout the State.

SAPONITE.

Found in Mitchell County, near Bakersville, in the cavities of the cellular hornstone of the chrysolite; popularly known as mountain tallow. Has not been analyzed.

HALLOYSITE.

Found near Salem, Forsyth County; is of an olive green color and waxy luster. The variety lithomarge occurs in Burke County.

A white, compact halloysite from Chatham County, analyzed by myself, gave:

Water	17·78
Silica	44·40
Alumina	36·88
Ferric oxide	0·95
	100·01

PINITE.

This mineral is found as a light gray to pale or dull greenish coating in the joints and seams and between the laminæ of the conglomeritic and felsitic slates of the Huronian series in the middle counties, and also in the granulites of the Blue Ridge. Has not been analyzed.

PARAGONITE.[1]

Is found in the so-called talcoid and talco-micaceous schists of the Piedmont section, especially in Burke, Caldwell, and Catawba; it is a common constituent of the soft brown and purple schists so common as to be characteristic of the region. It is also to be seen at Round Knob, in McDowell, in the altered schists and slates exposed in the railroad cuts, in similar rocks in Wake County, near Raleigh, and in many other localities. Has not been analyzed.

HISINGERITE (?).

The chloritic dust which coats the mica and dolomite of the Emerald and Hiddenite mine, in Alexander County, probably belongs to this species. Partial analysis by F. W. Clarke:

Ignition	20·50
Silica	31·16
Alumina	8·06
Ferric oxide	35·86
Magnesia	5·43
	101·01

The iron is undoubtedly present chiefly, but not wholly, as *ferrous* oxide; and the alumina is due to admixed mica. Very little material was available for the analysis.

[1] The species saponite, pinite, and paragonite are inserted upon the authority of the late Prof. W. C. Kerr. They need further investigation.

CULSAGEEITE.

The mineral which I had described as jefferisite from Culsagee, has been distinguished by Prof. Josiah P. Cooke, jr., as *culsageeite*. It occurs in broad laminæ or plated masses of a yellowish brown color, sometimes 4 or 5 inches in diameter, which when heated exfoliate in a remarkable manner. It is also found at the same locality in greenish, or brownish, yellow scales, not over one-eighth of an inch in diameter. Both varieties have been analyzed, the former by Geo. A. Koenig (I), the latter by Thos. M. Chatard (II). J. P. Cooke, jr., has also analyzed the large plates, but his analyses represent the mineral after having been dried at 100° C. (212° F.) by which operation it lost from 10·19 to 10·27 per cent of water.

	I.	II.	III (dried).
Sp. gr	.....	.....	2·225
Silica	33·93	34·00	37·58
Alumina	17·38	20·36	19·73
Ferric oxide	5·42	4·91	5·95
Ferrous oxide	0 50	0·42	0·58
Nickelous oxide	0·35	0·57	.....
Magnesia	23·43	21·71	25·13
Water	19·17	18·50	11·09
	100·18	100 47	100·06

It likewise occurs on Ivy River near Carter's, Buncombe County, at Carter's mine, Madison County, and in Henderson County, at Coleman's Station.

KERRITE.

Consists of innumerable fine scales of pale greenish yellow color and pearly luster. Exfoliates when heated, but less so than culsageeite. From the Culsagee mine.

Analyses (I) by T. M. Chatard, mean of two; and (II) by E. A. Schneider:

	I.	II.
Sp. gr	2·303	.....
Silica	38·29	38·13
Alumina	11·41	11·22
Ferric oxide	1·95	2·28
Ferrous oxide	0 32	0·18
Nickel oxide	0.25	0·48
Cobalt oxide	.....	trace
Magnesia	26·40	27·39
Water	21·25	20·47
	99·87	100·15

MACONITE.

Closely resembles fine, scaly culsageeite. Dark brown, with pearly luster, inclining to submetallic. Largely exfoliating, when heated. Numerous fragments of bluish gray corundum are embedded in it.

The carefully selected pure scales were analyzed by Thos. M. Chatard, who found as the mean result of two analyses:

Silica	34·22
Alumina	21·53
Ferric oxide	12·41
Ferrous oxide	0·32
Nickel oxide	0·12
Magnesia	14·46
Lithia	trace
Soda	0·51
Potash	5·70
Water	11·85
	101·12

Sp. gr., 2·827.

LUCASITE.

Similar to culsageeite in appearance, yellowish brown in color, and made up of small foliæ, not over 2mm. in diameter; also compact and disseminated; basal cleavage eminent; luster submetallic, somewhat greasy; exfoliates much on ignition; found associated with grass-green actinolite at Corundum Hill, Macon County; described by Dr. T. M. Chatard, whose analysis is as follows:

Water, expelled at 110° C	3·78
Water, at red heat	6·98
Silica	31·81
Alumina	12·99
Chromic oxide	0·54
Ferric oxide	5·29
Ferrous oxide	0·11
Manganous oxide	0·05
Magnesia	24·83
Lime	0·14
Soda	0·20
Potash	5·76
	100·48

PENNINITE.

The variety kämmererite, in violet and peach-blossom red scales, is associated with chromite at Culsagee in Macon County, Webster in Jackson County; Hampton's, Mining Creek, Yancey County; Rich Mountain, Watauga County, etc.; three-sided and six-sided plated crystals of a dark greenish and purplish color, associated with talc, etc., in the chrysolite beds at the same localities; also at Bakersville, Mitchell County, and Scott's Creek, Jackson County.

PROCHLORITE (AND CHLORITE).

Fine-grained, scaly prochlorite, of a dark green color, rarely in worm-like aggregations, is found associated with an albitic rock, from an alteration of which it has resulted, at the Steele mine, Montgomery County. At the Culsagee mine, prochlorite occurs as the result of the alteration of corundum, often showing the form and containing yet a core of the original mineral. Frequently the corundum has first changed into spinel and the latter has subsequently been altered into prochlorite, but in either case, where it touches the original mineral, it is frequently of a fine, scaly, pseudo-fibrous structure and becoming more laminated at a greater distance. But this is not always the case, as very often broadly foliated prochlorite is in immediate contact with corundum. Both the laminated and fine scaly form beds of considerable size. Under similar circumstances it is found at the Hogback mine in Jackson County, at Shooting Creek in Clay County, near Marshall, at the Carter mine in Madison County, and at many other corundum mines.

The so called corundophilite of Shepard, which was established by him on the prochlorite of Marshall, has no existence in North Carolina. Chlorite in scales and scaly aggregations is found in many of the gold and copper mines in the State, and chloritic slate at many localities throughout the whole slate belt, and in many counties outside of it, both in the Huronian and Montalban rocks.

I have analyzed the broadly foliated dark green variety (I), and the fine scaly variety diverging from corundum (II), both from Culsagee; and the fine scaly prochlorite from the Steele mine (III):

	I.	II.	III.
Silica	27·56	29·48	24·90
Alumina	22·75	22·22	21·77
Ferric oxide	2·56	0·70	4·60
Ferrous oxide	5·43	5·30	24·21
Nickelous oxide	0·30	0·11	.....
Manganous oxide		0·17	1·15
Magnesia	28·47	30·99	12·78
Water	13·80	11·63	10·59
	100·87	100·60	100·00

Analyses of other specimens from Culsagee, made by Thos. M. Chatard and J. L. Smith, gave similar results. It will be seen from these analyses that they are varieties in which a large portion of the ferrous oxide is replaced by magnesia.

A massive chloritic mineral in aggregations of minute scales, much resembling thuringite, has been found at Mount Pisgah, Iredell County. I have made an analysis of it, but as it was too much oxidized, the amount of ferrous oxide could not be ascertained with accuracy, and

therefore a doubt exists as to the species to which it belongs. The analysis gave:

Silica	24·22
Alumina	19·34
Ferric oxide	17·77
Ferrous oxide	20·98
Manganous oxide	0·07
Magnesia	5·72
Water	12·22
	100·32

Several other chloritic minerals from Corundum Hill have been analyzed by Dr. T. M. Chatard in the laboratory of the U. S. Geological Survey, but microscopic examination would be necessary to establish identity of species.

CHLORITOID.

In small scales of a greenish black color, disseminated through slaty pyrophyllite, from Evans's mill, in Chatham County. I have made an analysis of the carefully purified scales:

Silica	26·13
Alumina	40·11
Ferric oxide	3·44
Ferrous oxide	23·01
Manganous oxide	trace
Magnesia	0·94
Water	6·91
	100·54

Sp. gr., 3·353.

WILLCOXITE.

Greenish and grayish white fine scales of a pearly luster, much resembling talc, occur occasionally as the result of the alteration of corundum. One specimen from Shooting Creek, Clay County, is a fragment of a semi-globular mass with a core of white corundum; it also occurs in small quantity at Cullakenee, Clay County, and probably at Culsagee, Macon County.

Both, that from Shooting Creek (I) and that from Cullakenee (II), have been analyzed by George A. Koenig:

	I.	II.
Silica	28·96	29·50
Alumina	37·49	37·56
Ferric oxide	1·26	1·40
Ferrous oxide	2·44	2·38
Magnesia	17·35	17·20
Lithia	trace	trace
Soda	6·73	6·24
Potash	2·46	2·42
Water	4·00	3·32
	100·69	100·02

MARGARITE.

In small foliated masses of silver-white color and pearly luster, some of the folia showing planes of crystals associated with the corundum at the Culsagee mine (I); it has also been found with the mass of blue corundum found at Marshall, Madison County; but the most beautiful varieties are found at Cullakenee, Clay County, where it occurs in groups of laminated crystals, sometimes 2 inches long, 1½ wide, and five-eighths inches thick, of a slightly pinkish white color and pearly luster (II). These groups contain sometimes a nucleus of corundum, from which they are derived. The second variety from the same locality occurs in the form of broad laminæ of a pinkish color, intermixed with corundum and associated with zoisite (III); a third variety from Cullakenee is found in thin seams of a grayish green color, which are an aggregate of minute pearly scales of a greenish white and sea green color (IV). It is found rarely in Hogback mine, Jackson County. The gray corundum from Penland's, Clay County, is surrounded by a white and yellowish white cryptocrystalline and pseudofibrous margarite, and a similar incrustation is found upon the blue corundum at Crowder's Mountain.

A peculiar variety of soda margarite, of a compact and cryptocrystalline structure, surrounds the hexagonal corundum crystals from Hendrix's farm, near Belt's Bridge, Iredell County. It has been analyzed in the laboratory of the University of Pennsylvania by Frank Julian (V). I have analyzed the margarite from Culsagee (I); Thos. M. Chatard the first variety (II), and I the second (III) and third (IV) varieties from Cullakenee:

	I.	II	III.	IV.	V.
Sp. gr.	3·087	2·990	3·055	3·064	.....
Silica	28·11	29·34	30·72	29·63	33·10
Alumina	49·16	48·73	49·83	51·19	52·20
Chromic oxide	.....	.....	.....	0·13	.....
Ferrous oxide	0·43	0·78	0·84	0·59	trace
Magnesia	0·45	0·78	0·76	1·09	.....
Lime	11·08	11·32	10·84	11·28	8·44
Lithia	0·45	trace	trace	.....	.....
Soda	0·67	2·61	2·19	1·22	2·59
Potash	0·22	0·10	0·26	0·20	.....
Water	6·43	6·55	6·21	4·73	4·85
Corundum	3·31	.....	.....	.....	.....
	100·31	100·21	101·65	100·06	101·18

DUDLEYITE.

Found in small quantity in soft, bronze colored or brownish yellow scales with pearly luster, slightly exfoliating when heated. They are probably the result of the alteration of margarite, and are found with it rarely at the Cullakenee mine, Clay County.

URANOTIL.

About one-third of the so-called "gummite" is an admixture of uranotil, but this mineral is also obtained in a nearly pure state by the further decomposition of the uraninite or rather gummite. It is then found in apparently amorphous, compact masses, without or with a waxy luster, and a pale straw or lemon yellow color; opaque and of uneven fracture; sp. gr. 3.834; incrusting the gummite, but sometimes the whole mass of the nodules changed into uranotil.

The mean result of two analyses which I made is:

Silica	13·72
Uranic oxide	66·67
Plumbic oxide	0·60
Baryta	0·28
Strontia	0·13
Lime	6·67
Phosphoric acid	0·29
Water	12·02
	100·38

From the Flat Rock mine, Mitchell County. Found also with gummite at the Deake, Lewis & McHone mines.

The late Prof. W. C. Kerr also reported "uranochre" as a yellow to orange incrustation from Gibbs's mine, Yancey County, and the Flat Rock and Buchanan mines in Mitchell County. "Zippeite" is given by him on the authority of Julien as occurring at the Higdon mine, Macon County. Both species are extremely doubtful, and may be only varieties of uranite and phosphoranylite.

THORITE.

Identified by Penfield both microscopically and chemically as a mechanical admixture in the monazite sands of Brindletown, Burke County.

AUERLITE.

A new species discovered by Hidden and Mackintosh at the Zircon mine, in Henderson County, and also at Price's farm, 3 miles southwest of the first-named locality. Color, pale yellow to orange and brownish red. Hardness, 2·5 to 3; sp. gr. 4·4 to 4·766. Very brittle and easily crumbled. Form like zircon, and the crystals, simple in habit, are often attached to zircon in parallel position. Twins, like those of zircon, have been observed.

Analyses by Mackintosh:

	I.	II.	III.
Water	9·88	11·21	.....
Carbonic acid	1·00		
Silica	.....	7·64	8·25
Phosphoric acid	.....	7·46	7·59
Thorium oxide	.....	70·13	.....
Ferric oxide	.....	1·38	.....
Lime	.....	0·49	.....
Magnesia	.....	0·29	.....
Alumina, etc	.....	1·10	.....
	.....	99·70	.....

The lemon yellow variety found on the Price land has a sp. gr. of 4·03 to 4·08, and is richer in phosphoric acid and poorer in silica than the foregoing mineral. The data are water, 10·64; phosphoric acid, 8·58; silica, 6·84. The thoria determination was lost.

XANTHITANE.

Although not a silicate this mineral may best be placed here. It occurs abundantly in the Zircon mine at Green River, Henderson County, and is a yellow, earthy pseudomorph after titanite. The crystalline form is often well shown, and the xanthitane frequently contains an unaltered core of titanite, from which mineral it has been derived. Analysis by L. G. Eakins:

Water lost at 100° C	6·02
Water lost at red heat	9·92
Silica	1·64
Titanic oxide	57·46
Alumina	16·41
Ferric oxide	4·16
Lime	0·84
Magnesia	trace
Phosphoric acid	3·89
	100·34

Sp. gr., 2.941 at 24° C.

The mineral is evidently an aluminous clay, containing titanium in place of silicon.

TANTALATES, COLUMBATES.

PYROCHLORE OR MICROLITE.

Microscopic brownish yellow or honey yellow grains, and crystals which appear to be octahedra with dodecahedral planes, are associated with orthoclase, tourmaline, etc., at Ray's mica mine, on Hurricane Mountain, Yancey County, and are probably pyrochlore or perhaps microlite. Larger octahedra are reported to have been found at the Flat Rock mine in Mitchell County, and were called microlite. I have never seen any; those sent to me as microlite were garnet.

HATCHETTOLITE.

In octahedral crystals with cubical planes, of a yellowish brown color, with grayish opalescence, resinous luster, and subconchoidal fracture. Hardness, 5; sp. gr., 4.851.

Three analyses of it have been made by J. L. Smith, the mean results of which I give (I), and one by O. D. Allen (II):

	I.	II.
Tantalic oxide	67·04	29·83
Columbic oxide		34·24
Titanic oxide	.....	1·61
Tungstic oxide	0·75	0·30
Stannic oxide		
Plumbic oxide	trace	trace
Uranic oxide	15·61	15·50
Ferrous oxide	2·24	2·19
Cerous oxide	1·17	.....
Yttria		
Magnesia	.....	0·15
Lime	7·31	8·87
Soda	.....	1·37
Potash	0·86	trace
Loss by ignition	4·87	4.49
	99·85	98.55

Found with samarskite at Wiseman's mine, Mitchell County.

TANTALITE.

A massive variety of tantalite, weighing a few ounces, has been collected by the late Prof. F. H. Bradley, in Yancey County. It had a black color and a specific gravity of 6·88; and has been analyzed by W. J. Comstock, who found:

Tantalic oxide	59·92
Columbic oxide	23·63
Ferrous oxide	12·86
Manganous oxide	3·06
Magnesia	0·34
	99·81

COLUMBITE.

It occurs in crystals and crystalline masses of a black color embedded in the samarskite of Wiseman's mine, Mitchell County. It has also been found at the Deake mine and other localities in the same county, at Ray's mine in Yancey County, near Burnsville; at Balsam Gap mine in Buncombe, and near Franklin, in Macon County. One crystal of it was kindly sent me by Mr. J. A. D. Stephenson, of Statesville, which he had found at Isaac Price's farm, White Plains, Alexander County. I have a crystal of about 2 inches in length, 1½ in width and

½ in thickness, from Capt. Mills's mine, Burke County, which appears to belong to this species.

J. L. Smith has analyzed the crystals (I) and massive varieties (II) from Wiseman's mine, and I that from Isaac Price's farm (III):

	I.	II.	III.
Sp. gr.	5·562	5·485	5·758
Columbic and tantalic oxides	80·06	80·82	79·90
Tungstic and stannic oxides	1·21	1·02	0·56
Ferrous oxide	14·14	8·73	15 14
Manganous oxide	5·21	8 60	5 09
Cupric oxide	.....	trace	....
	100·62	99·17	100·92

YTTROTANTALITE (?).

According to Gen. Clingman, grains of this mineral have been found in several localities in the western counties. It is probably fergusonite or samarskite.

SAMARSKITE.

It has been found in the gold sands of Rutherford County, in small black grains and pebbles, sometimes weighing one-fourth of an ounce, which, when broken, had a vitreous resinous luster and a brownish black color, and a sp. gr. of 5·69. It is found also in the gold sands of Burke (at Capt. Mills's) and McDowell Counties. It has been analyzed by T. S. Hunt (I).

About 5 years ago large masses, one of them weighing more than 20 pounds, were found at Wiseman's mine, Mitchell County; usually in irregularly shaped pieces, sometimes coarsely crystallized, rarely in distinct modified rhombic prisms. The color is deep velvet black, in thin edges brown, the luster resinous, and the fracture conchoidal. Sp. gr., 5·72.

It has been analyzed by Miss Ellen H. Swallow (now Mrs. R. H. Richards) (II), J. L. Smith (III), and O. D. Allen (IV):

	I.	II.	III.	IV.
Columbic oxide	54·81	54·96	55 13	37·20
Tantalic oxide				18·60
Tungstic and stannic oxides	.....	0·16	0·31	0·08
Uranic oxide	17·03	9·91	10·96	12·46
Ferrous oxide	14·07	14·02	11·74	10·90
Manganous oxide	.....	0·91	1·53	0·75
Cerous oxide, etc	3·95	5·17	4·24	4·25
Yttria	11·11	12·84	14·49	14·45
Magnesia	.....	0·52	trace.	.....
Lime	.....	.....	.....	0·55
Loss by ignition	0·24	0·66	0·72	1·12
Insoluble	.....	1·25	.....	.....
	101·21	100·40	99·12	100·36

Dr. Smith expresses his doubts about the true nature of the cerous oxide, etc., separated from the samarskite. This mineral has lately been the subject of investigation by numerous chemists, and several new elements, samarium, etc., have been discovered in it. The nature of these has not yet been sufficiently established to understand their exact relations. Samarskite has also been found in small pieces of 1 to 3 ounces at the Grassy Creek mine, Mitchell County, and in McDowell County.

A mineral associated with samarskite, and probably a product of its decomposition, has erroneously been called euxenite.

It occurs in reddish brown and hair-brown masses, translucent in thin fragments and with irregular to subconchoidal fracture, a yellowish brown streak, and a resinous to subadamantine luster. Hardness, 5·5 It has been analyzed by J. L. Smith (I) and M. H. Seaman (II):

	I.	II.
Sp. gr.	4·593 to 4·642	4·33
Columbic oxide	54·12	47·09
Stannic and tungstic oxides	0·21	0·40
Yttria	24·10	13·46
Cerous oxide		1·40
Lanthana and didymia	.....	4·00
Uranic oxide	9·53	15·15
Ferrous oxide	0·31	7·09
Manganous oxide	0·08	.....
Lime	5·53	1·53
Water	5·70	9·55
	99·58	99·67

RUTHERFORDITE.

In monoclinic crystals and grains of a blackish brown color and vitreo-resinous luster and conchoidal fracture. Sp. gr., 5·55–5·69.

A partial analysis by T. S. Hunt gave:

Titanic oxide	58·5
Lime	10·0
Not determined	31·5
	100·0

In the gravel deposits of Rutherford and Burke Counties.

These data give no clue to the identity of the mineral. It may be the same as the following.

FERGUSONITE.

Found by Hidden in July, 1879, at Mills's gold mine, Brindletown, Burke County. It occurs in small, reddish brown to brownish black, tetragonal, very acute pyramids, with basal and hemihedral planes,

generally covered with a gray crust. Also found by Hidden at the Wiseman mine, in Mitchell County, in fine crystals, but with nothing new as to form.

The Brindletown fergusonite has been analyzed by J. L. Smith (I) and J. W. Mallet (II), as follows:

	I.	II.
Sp. gr.	5·87	.....
Columbic oxide	48·12	43·78
Tantalic oxide		4·08
Stannic and tungstic oxides	.....	0·76
Yttria	40·20	37·21
Cerous oxide		0·66
Lanthana nd didymia		3.49
Uranic oxide	5.81	5·81
Ferrous oxide	2·75	1·81
Lime	.....	0·65
Water	1·50	1·62
	98·38	99·87

POLYCRASE.

Discovered by Hidden in decomposing granite on the Davis land, not far from the zircon mine in Henderson County. It occurs in separate crystals, associated with zircon, monazite, xenotime, cyrtolite, and magnetite. More or less altered at the surface to a mineral resembling xanthitane or gummite; color, nearly coal black; sp. gr., 4·78. A partial analysis by Mackintosh gave as follows:

Columbic oxide, Tantalic oxide, Titanic oxide	48·97
Yttria, etc	27·55
Ferric oxide	3·19
Uranic oxide	13·77
Ignition	5·18
	98·66

Additional experiments gave columbic oxide, 28·52, and titanic oxide, 20·27. The same mineral also occurs near Marietta, South Carolina, which is in the same general region.

ROGERSITE.

In white mammillary crusts and little pearly beads upon samarskite at the Wiseman mine, Mitchell County. Sp. gr., 3·313.

It has been partially analyzed by J. L. Smith, who found:

	I.	II.
Columbic oxide	18·10	20·21
Yttria, etc	60·12	.....
Water	17·41	18·34

PHOSPHATES, ARSENATES, ETC.

XENOTIME.

In minute tetragonal pyramids, in the sands from gold washings in Polk, McDowell, Burke, and Rutherford Counties. In some sands which I have received from Capt. Mills's gold mine, in Burke County, there were a few peculiar crystals of a pale grayish or yellowish white color. They were tetragonal pyramids, but were irregular and rough on the planes, and appeared to inclose some foreign substance, perhaps zircon. One had a nucleus of a greenish yellow color and resinous luster, which resembled monazite. A few tests which have been made with a fragment of a crystal, which appeared pretty uniform in composition, gave reactions resembling those of zirconia, yttria, and phosphoric acid, with a minute trace of cerous oxide.

Some very fine crystals of xenotime have also been found by Hidden at a locality about 3 miles from the Emerald mine, in Alexander County; sp. gr., 4·52. He also verifies the Brindletown mineral, and reports it from the Davis land on Green River, in Henderson County. At both the latter localities the xenotime crystals are sometimes symmetrically compounded with zircon, like the crystals from Norway described by Zschau.

APATITE.

This is rather a rare mineral in this State. I have observed it in imperfect crystals of a grayish and reddish green color in orthoclase, etc., at Ray's mine, Hurricane Mountain, Yancey County, and in small granular patches of a greenish color in granite; found 3 miles south of the Blue Ridge, 16 to 17 miles from Jefferson, on the road to Wilkesborough; found also in greenish white crystals, often inclosing quartz, sometimes from 2 to 3 inches in length and nearly 1 inch in thickness, implanted in albite, at Point Pizzle and at Cox's mine, Mitchell County, and at the Presnel and Gugenheim mines, Yancey County.

Minute crystals of apatite of highly interesting forms, with many planes, are found at the Emerald and Hiddenite mine in Alexander County; and opaque, minute, hexagonal prisms with pyramidal and basal planes are found in cavities of orthoclase, associated with the zircons of Green River, Henderson County.

Prof. W. B. Phillips has described phosphatic deposits similar to those of South Carolina, but nowhere in sufficient amount to give full assurance of economic importance, in eastern North Carolina in the counties of Duplin, Brunswick, Pender, and others. The best deposits opened occur 4 to 8 miles northeast of Magnolia, in Duplin County, where they form thin, irregular beds from 8 to 12 inches in thickness in sand deposits from 3 to 5 feet below the ground.

PYROMORPHITE.

This is one of the most beautiful minerals found in North Carolina, and formerly was quite abundant at the Silver Hill mine, which furnished very handsome specimens of hexagonal prisms and crystalline aggregations of different shades from colorless to almost black, also honey and wax yellow, green, brown, etc.; less abundant, and mostly of a yellowish green color, it is found at Silver Valley, Davidson County. In green and yellowish green crystals at the Troutman and McMakin mines, in Cabarrus County; also at the Stewart mine, in Union County, and in minute green crystals in the gold veins of the Baker and Miller mines, Caldwell County.

MONAZITE.

It is found in considerable quantities in small, brown, greenish, or yellowish brown monoclinic crystals in the gold sands of Rutherford, Polk, Alexander, Burke, and McDowell Counties; also in the neighborhood of Crowder's Mountain, Gaston County, and at Todd's Branch, in Mecklenburg County, where it occurs in association with diamond, zircon, etc.

Very fine crystals over an inch long were found by Hidden in Mitchell County. It is also found in mica-schist at the Deake mine, Mitchell County; in feldspar at Ray's mine, Yancey County, and in large cleavable masses, sometimes 3 to 4 inches across and of a yellowish brown color, from Mars Hill, Madison County.

Monazite is especially abundant in the gold sands at Brindletown, Burke County. About 15 tons of a sand containing from 60 to 92 per cent of small crystals have been found, the color varying from wax yellow to cinnamon brown; sp. gr. 5·10. Analyzed by Penfield, in triplicate, as follows:

	I.	II.	III.
Phosphoric acid	29·45	29·20	29·20
Cerium oxide	31·38	31·04	30·77
Lanthanum oxide	} 30·67	30·80	31·17
Didymium oxide			
Thorium oxide	6·68	6·24	6·56
Silica	1·40	.....	.....
Water, or loss by ignition	0·20	0·20	.....
	99·78	.....	.....

The thoria is due to admixed thorite. About 3 miles east of the Alexander County emerald mine some exceptionally fine crystals of monazite were found, says Hidden, associated with smoky quartz, rutile, and xenotime. They were mostly transparent, highly polished, and of a fine essonite-red color. They varied from one fourth to one

half an inch wide and from one-third to three-fourths of an inch long; sp. gr., 5·203. Penfield found in this monazite only 1·48 per cent of thoria.

VIVIANITE.

Found in dark bluish green, slender crystals, in a compact nodule of tertiary marl, in Edgecombe County; analyzed by W. B. Phillips, of the agricultural chemical station. It is a new and unnamed variety, resembling anglarite and ludlamite in its percentages of water (14) and iron oxide (56), but differing from both and occupying an intermediate position between them in containing equal percentages of both forms of the oxide—protoxide 28·05, sesquioxide 28·35. The normal *ferrous* oxide of vivianite is here, as usual, oxidized in part to the *ferric* form.

OLIVENITE.

Minute green crystals and brownish green, fibrous masses, associated with tetrahedrite, scorodite, etc., at George Ludwick's mine, in Cabarrus County, appear to belong to this species.

PSEUDOMALACHITE.

In reniform and fibrous masses, of a dark emerald green color, at the McGinn and Wilson mines, in Mecklenburg County; Cullen's mine, in Cabarrus County; Fisher Hill mine, in Guilford County; at Clegg's mine, in Chatham County, and about 1 mile from the Soapstone quarry, in Moore County; also at the Peach Bottom mine, in Alleghany County.

I have analyzed the pseudomalachite from the McGinn mine, which contains:

Phosphoric acid	24·58
Cupric oxide	68·60
Water	6·86
	100·04

LAZULITE.

In dark blue crystals and crystalline masses, in quartz, and associated with cyanite and muscovite at Crowder's and Clubb's Mountains, in Gaston County; also in quartz, and with very little muscovite, at Coffee Gap, in the Sauratown Mountains, Stokes County. That from Clubb's Mountain has been analyzed by Smith and Brush, who found in two analyses:

	I.	II.
Sp. gr.	3·122	.....
Phosphoric acid	43·18	44·15
Alumina	31·22	32·17
Ferrous oxide	8·29	8·05
Magnesia	10·06	10·02
Water	5·68	5·50
Silica	1·07	1·07
	99·70	100·96

SCORODITE.

In small, leek green and yellowish green crystals, associated with tetrahedrite, quartz, etc., at George Ludwick's mine, in Cabarrus County. It is found in finely granular masses of a brownish or yellowish green color, associated with leucopyrite, from the oxidation of which it is formed, at Drum's farm on the White Plains, Alexander County, and at Dr. Halyburton's, in Iredell County.

WAVELLITE.

Globular and hemispherical aggregations of white and grayish white wavellite, associated with silver, galenite, pyrite, etc., are rarely met with at Silver Hill, Davidson County.

PHARMACOSIDERITE.

Exceedingly minute crystals of this mineral, of a brownish green color, are associated with the scorodite of George Ludwick's mine, Cabarrus County.

DUFRENITE.

It is rarely met with in grayish green tufts of silky luster with the so-called "black band" iron at Egypt, Chatham County.

PHOSPHURANYLITE.

In microscopic rectangular pearly scales or in pulverulent incrustations upon quartz, muscovite, and feldspar. Deep lemon yellow in color.

I have made an analysis of a specimen, which appears to have been slightly contaminated with cerussite, and found the composition, after deducting the plumbic oxide, as follows:

Uranic oxide	76·71
Phosphoric acid	12·08
Water	11·21

Associated with autunite and other uranium minerals at the Flat Rock mine and Buchanan mine, Mitchell County.

AUTUNITE.

In beautiful nearly square scales or small crystals of a greenish, yellow or yellowish green color, upon quartz and feldspar at the Flat Rock and other mines, Mitchell County. Hidden also reports it from Alexander County.

NITER.

Crystalline crusts on mica slate at Nantahaleh River, in Cherokee County.

TUNGSTATES, MOLYBDATES, ETC.

WOLFRAMITE.

In laminated masses with cuproscheelite and scheelite at the Cosby mine, and with barite at the Flowe mine, both in Cabarrus County; also, according to Gen. Clingman, frequently in Rutherford and Burke Counties.

I have made an analysis of the wolfram, which forms the nuclei in the rhombic tungstate of lime and found:

Ferrous oxide	19·80
Manganous oxide	5·35
Lime	0·32
Stannic oxide	trace
Tungstic oxide	75·79
	101·26

Sp. gr., 7·496.

RHOMBIC TUNGSTATE OF LIME.

Associated with wolframite, in barite, at the Flowe mine, in Cabarrus County, in small crystals and laminated masses of a yellowish and grayish color, which frequently contain a nucleus of wolfram.

SCHEELITE.

Orange-colored tetragonal pyramids are found at the Flowe mine; yellowish brown and grayish imperfect crystalline masses at the Cosby mine; also at Cullen's mine, Cabarrus County, in rounded granular patches of a grayish-yellow color, with auriferous pyrite in quartz. I have analyzed the latter and found them composed of:

Stannic oxide	0·13
Tungstic oxide	79·52
Cupric oxide	0·08
Ferric oxide	0·18
Lime	19·13
	99·22

CUPROSCHEELITE.

In yellowish green and siskin green pulverulent coatings upon scheelite at the Cosby mine, Cabarrus County.

STOLZITE.

A few small tetragonal pyramids of a bluish gray, and one small, somewhat barrel-shaped crystal of a grayish yellow color of this very rare mineral have been found in a lump of quartz, associated with sphalerite, at Silver Hill, Davidson County.

SULPHATES, CHROMATES, ETC.

BARITE.

In small white tabular crystals, with pyromorphite and manganese ores at the McMakin mine, Phœnix mine, and White's mine, Cabarrus County. The laminated and coarsely granular white variety at the Flowe mine and Orchard vein, in Cabarrus County; a vein of the coarsely laminated, grayish white barite, at the Latta mine, near Hillsboro', Orange County. It occurs coarsely granular, and has the appearance of white marble, at Col. Walkup's, Union County. A vein of very white compact and granular barite of from 7 to 8 feet in width has been found at Crowder's Mountain, Gaston County; west of the Blue Ridge, a vein of 8 feet in width exists at Chandler's, 9 miles below Marshall, in Madison County, where it is white and grayish white in color, and of a granular structure, containing small patches of laminated barite; also on Elkin Creek, in Wilkes County.

ANGLESITE.

In small, tabular, rhombic prisms, with very few additional planes, in the brown, granular zincblende of Silver Hill, Davidson County; also, according to Gen. Clingman, at the Baker mine, in Caldwell County.

CROCOITE.

I have observed this rare mineral associated with gold and small quantities of galenite in small cavities of saccharoidal quartz from Nash County, in very minute, dark hyacinth red crystals.

MELANTERITE.

As the result of the decomposition of pyrite, disseminated through many of the mica slates, etc., of Rutherford, Cleveland, and other counties, melanterite or copperas is formed, but no good crystallized specimens have come to my notice.

GOSLARITE.

In the water of the Silver Hill mine; also in fine, fibrous, crystalline masses upon sphalerite, formerly at the McMakin mine, Cabarrus County.

CHALCANTHITE.

Very fine crystals, with granular and fibrous crystalline masses of sulphate of copper, were formerly obtained from the upper works of the Silver Hill mine, Davidson County, principally at the 60-foot level.

ALUNOGEN.

I have once seen a beautiful specimen of fibrous, silky alunogen from the western counties, but could not learn the exact locality from which it came. It is found abundantly associated with melanterite, in Rutherford, Cleveland, and other counties, but not in good specimens; also in Iredell and Catawba Counties.

MISY.

This mineral has been observed in association with galenite and pyrite, in pulverulent greenish yellow masses, at Flint Knob, Wilkes County.

MONTANITE.

This very rare tellurate of bismuth has been found with tetradymite at David Beck's mine in Davidson County, and at Captain Mills's, in Burke County. The yellow "oxide of bismuth," observed by Dr. Asbury at the Asbury vein, in Gaston County, may belong to this species.

An analysis which I have made of that from Davidson County gave:

Ferric oxide	1·26
Cupric oxide	1·04
Bismuthic oxide	68·78
Telluric acid	25·45
Water	3·47
	100·00

CARBONATES.

CALCITE.

Perfect crystals are found at Whiteville, Columbus County, in marl, in the Clegg mine, Chatham County, and at the Emerald and Hiddenite mine, in Alexander County. It occurs coarsely granular in a vein at Hoover's mine, about 6 miles from Silver Hill; at Moore's mine, 10 miles southeast of Lexington; in Ore Knob mine, Ashe County; and rarely at Silver Hill, in Davidson County, and the Steele mine, Montgomery County. Small quantities of granular calcite were found in digging a well at Morrisville, Wake County. The granular varieties, which constitute marble, are sometimes found associated with the compact varieties of limestone in the band which passes through North Carolina, from Stokes County through Catawba, Lincoln, and Gaston Counties; as, for instance, at the quarries of Martin on Snow Creek; of Bolejack, near Germanton, in Stokes County; Pfaff in Forsyth; Hooper, in Catawba; and Stowe, in Lincoln County, and in the Eocene limestone of New Hanover County. A coarse, granular limestone occurs also at Goshen and at Haskett's, on Ellijay Creek, Macon County, and on Cullowhee Creek, Jackson County, again on Bear Creek and *Walnut* Creek and at Marshall, in Madison County. A veined gray

and white marble is found at Powell's quarry, near Catawba station, Catawba County. Very beautiful varieties of white, pink, and gray marble are found abundantly at the Nantahaleh River, Marble Creek, Valley River, and other places in Cherokee County. A band of compact limestone, sometimes finely granular, is found in Turkey Cove and Cedar Cove and on Linnville Mountain and Graveyard Mountain, in McDowell County; also in Jackson, Transylvania, and Henderson Counties, and at Warm Springs and on Shut In Creek and Laurel River, Madison County. It is also found in small seams and crystalline grains, replacing in part the orthoclase of a massive granite gneiss in Harnett County.

DOLOMITE.

Dolomite of a grayish white color, resembling marble, is found on Valley River, 10 miles from Murphy, Cherokee County; and in magnificent rhombohedral crystals, often coated with hisingerite, at the Emerald and Hiddenite mine in Alexander County.

MAGNESITE.

The lamellar white and grayish variety, from which distinct cleavage crystals can be obtained, is found at McMakin's mine, Cabarrus County; also, with chrysolite at Webster, Jackson County, and Hampton's, Mining Creek, Yancey County. At the latter locality are also found the white compact, and at Webster the white earthy and pulverulent varieties. Breunnerite occurs in serpentine, 4 miles south of Morganton, Burke County, and near Dobson, Surry County.

SIDERITE.

In fine rhombohedral crystals at the Emerald and Hiddenite mine, and also formerly at the McCulloch, the North Carolina, and several other mines in Guilford County, where it occurred in considerable masses in the vein. In the same manner it is of frequent occurrence in many of the gold veins of the State, especially in those which carry copper. It often forms almost the whole mass of the veins, frequently, however, decomposed into limonite, which still retains its rhombohedral form; for instance, at Conrad Hill in Davidson County, in Gaston County, at some of the mines in Randolph County, and at the Cosby mine in Cabarrus county. In smaller quantities it has been observed in Stokes County and in some of the mines in Mecklenburg and Alexander Counties. A white cleavable variety occurs at the Rudisill mine, near Charlotte. The earthy and argillaceous varieties of siderite form large beds in the Triassic coal strata and constitute the so-called black band or ball ore at Farmville, Egypt, the Gulf, etc., in Chatham County. It is also found in compact, grayish brown nodules in Halifax and Granville Counties.

RHODOCHROSITE.

In small globular pink and rose-red concretions, with earthy manganese, near Franklin, in Macon County; also mixed with magnesite, talc, etc., in compact and granular masses, at the McMakin mine, Cabarrus County.

CERUSSITE.

The most beautiful crystallizations, single individuals as well as twins, were found at Silver Hill, immediately after the discovery of of the mine; also white, yellowish, and greenish white, compact varieties, frequently highly argentiferous. A very interesting occurrence at the same mine is cerussite, pseudomorphous after pyrite. Yellowish white columnar cerussite occurs in Gaston County. Rhombic prisms with pyramidal planes, together with imperfect crystallizations and earthy masses, are found at Clegg's mine, Chatham County. At Elk Creek, in Wilkes County, earthy cerussite has been observed coating galenite. It is also found at Baker mine in Caldwell County, and at Murphy, Cherokee County.

MALACHITE.

Malachite, in its varieties, fibrous, compact, and earthy, being the result of the decomposition of other copper ores, is found in association with the latter in almost every copper mine in the State. The Guilford, Cabarrus, and Mecklenburg County copper mines contain it. I have observed the fibrous variety at Silver Hill and Conrad Hill, in Davidson County; the Gillis mine, in Person County; the Cheek mine, in Moore County, and both the fibrous and earthy malachite at Clegg's mine, in Chatham County. It has been found in the Brushy Mountains, Alexander County; the Peach Bottom mine, Alleghany County; the Ore Knob mine, in Ashe County; the Gap Creek mine, in Watauga County; the Cullowhee, Savannah, and Waryhut mines, in Jackson County; near Sassafras Fork, in Granville County, and at many other localities too numerous to be mentioned. Pseudomorphs of malachite, after cubical cuprite, have been found at Cullen's mine, Cabarrus County.

AZURITE.

This variety of carbonate of copper is far less frequently met with. Small but very beautiful and perfect crystals are found at Clegg's mine and at Snipes's (iron) mine, in Chatham County, and at the Cheek mine, in Moore County. It is rare at the Cullen and Boger mine in Cabarrus County, the Wilson mine in Mecklenburg County, and at Wells's, Gaston County.

BISMUTITE.

In yellowish white concretions, often of a pearly luster, or white incrustations upon gold-bearing quartz, at the Asbury mine, in Gaston County, where it was discovered by Dr. Asbury.

Bismutite has also been found in a narrow vein in Casher Valley, Jackson County, in small masses, the largest of the size of a pigeon's egg, of a light apple-green or dark gray, through yellow to light gray masses which are chalky white in the amorphous parts. Laminated, sometimes almost columnar. Sp. gr., 7·4 to 7·5. The analyses by Dr. A. H. Chester gave:

	I.	II (the pure).
Bismuthic oxide	86·36	89·80
Carbonic dioxide	7·79	8·10
Water	2·02	2·10
Insoluble	3·6	.....
	99·80	100·00

Quite recently (January, 1888) I have received the same mineral from Rev. C. D. Smith, from Highlands, Macon County, where it occurs in amorphous, grayish white masses, associated with beryl, muscovite, etc.

MINERAL COAL.

ANTHRACITE.

A very interesting occurrence of anthracite is that of masses with conchoidal fracture in the vein rock at the Clegg mine in Chatham County. The bituminous coal, both of the Deep and Dan Rivers, is frequently, especially near trap dikes, almost deprived of its hydrocarbons, often approaching true anthracite.

BITUMINOUS COAL.

The greater portion of the coal in the Deep River beds is bituminous coal, the volatile matter varying from about 8 to 32 per cent. The Dan River coal, which I had opportunity to examine, is so-called semi-bituminous coal, that from near Stokesburg, Stokes County, containing about 10 per cent of volatile matter.

LIGNITE OR BROWN COAL.

Frequently met with in the marl beds of the eastern counties, and in the Trias of Granville County, on Tar River, and on Brown's Creek, Anson County.

ORGANIC COMPOUNDS.

SUCCINITE (AMBER).

Found in lumps of several ounces weight in Pitt County and elsewhere, in the Tertiary marl beds of the eastern counties.

SYNOPSIS OF MINERALS AND MINERAL LOCALITIES, BY COUNTIES.

ALAMANCE.

Graham.—McAden mine: Gold; pyrite; actinolite.

Newlin's.—Gold; pyrite; chalcopyrite.

Holt mine.—Gold; also at Anthony mine.

Dixon's mine.—Gold on both sides of Haw River, in placers; Boyd mine, in placers.

Cane Creek Mountains.—Gold; epidote; chalcedony; magnetite.

Near Cane Creek Factory.—Pyrophyllite; halloysite.

ALEXANDER.

White Plains.—Scorodite; columbite; tourmaline (Lackey's and Price's); beryl (at Warren's, Lackey's, and Price's); rose quartz; smoky quartz, also near Taylorsville; rutile in geniculated crystals, and acicular crystals in limonite and in quartz; the latter also near Poplar Springs; spodumene, in emerald and yellowish green crystals (hiddenite), in Sharpe's township.

Barrett Mountain.—Graphite.

Price and Keever place.—Beryl; tourmaline; columbite; autunite; muscovite.

Lead mine.—Amethyst.

Roseman's farm.—Milky quartz.

Little River.—Tourmaline.

Hiddenite Post office.—(The Emerald and Hiddenite mine)—Emerald (!); beryl (!); monazite in fine crystals (!); spodumene, transparent, green, and yellowish crystals (!); apatite; calcite; dolomite (!); siderite; rutile (!); muscovite (!); hisingerite; tourmaline.

Taylorsville.—Three miles distant, smoky quartz; rock crystal; tourmaline; beryl.

Headwaters of Snow Creek.—Foliated talc; hematite.

Bend of Catawba River.—Pyrope garnets.

Marshall's farm.—Garnets.

Brushy Mountains.—Malachite; chalcopyrite; graphite; asbestus; tabular quartz.

Elsewhere.—Green, brown, and black tourmaline; graphite; magnetite; tantalite; beryl, yellow, blue, green; quartz crystals with basal

plane, also with other singular modifications, also smoky, yellow, and milky; monazite, var. turnerite; asbestus; pyrite; magnetite; chalcopyrite; pyrolusite; limonite, pseudomorphous after siderite; siderite; kaolinite; orthoclase, large crystals (one of 40 pounds); biotite; muscovite; rutile, very fine at Milholland's mill and at Robt. Johnson's; tourmaline at B. Lyon's, with unusual terminal angles (Hidden).

ALLEGHANY.

Peach Bottom mine.—Pyrite; chalcopyrite; malachite; galenite; cuprite; sphalerite; molybdenite.

Roaring Gap.—At H. Harris's, chalcopyrite (auriferous); bornite.

T. Bryan's.—Pyrite.

Bullhead Mountain.—Cyanite; magnetite; garnet.

Elsewhere.—Graphite; chrysolite; gold, in placers; martite; pyrite; calcite; zoisite; smoky quartz.

ANSON.

Boggan's Cut.—Calcite; serpentine; rock crystal and cellular quartz; lignite.

Mill Creek.—Muscovite.

Peedee Station.—Orthoclase.

Farm of T. J. Pack.—Siderite; chalcopyrite; quartz.

Wadesboro'.—Two miles south, gold in vein.

Elsewhere.—Quartz crystals of considerable size, at several points.

ASHE.

Blue Ridge, south of Jefferson.—Muscovite; black tourmaline.

Horse Creek.—At Hampton's: epidote; magnetite; manganese garnet. At Graybill's: magnetite; epidote.

Helton Creek, near mouth.—Magnetite at Ballou's.

Ore Knob mine.—Pyrite; calcite; chalcocite; arsenopyrite; malachite; metallic copper.

Jefferson.—Chalcopyrite, 2, 3, and 6 miles distant, and at Mulatto Mountain; graphite in gneiss; chlorite at Willis's mine; hyalite at Foster's mica mine; muscovite, beryl, and garnet at Little Phœnix mica mine; kaolin; tourmaline, 7 to 8 miles southeast; chrysolite, 6 miles east on New River.

Three Top Mountain.—Tremolite.

New River (South Fork, near mouth).—Chrysolite; chalcopyrite, magnetite.

Gap Creek (Copper Knob mine).—Gold; silver; hematite; epidote; bornite; chalcocite; chalcopyrite; chrysocolla; malachite. On Gap Creek: cyanite; hornblende.

Shady Spring.—Asbestus.

Elk Knob.—Chalcopyrite; epidote.

Phœnix Mountain.—Rock crystal (!).

Witherspoon mine.—Asbestiform actinolite.

Elsewhere.—Azurite; cuprite; actinolite; talc; chlorite; asbestus; graphite.

BEAUFORT.

Siderite, in nodules; calcite in marl beds, and in the Eocene (bottom of Pamlico River, and on Blount's farm); pyrite.

BERTIE.

Calcite, in marl beds.

BLADEN.

Calcite, in marl beds.

BRUNSWICK.

Calcite, in marl beds; glauconite, in green sand; phosphatic nodules.

BUNCOMBE.

Asheville.—Meteoric iron (!); garnet; magnetite, at L. W. Sams's; ferrous chloride (!), in the meteorite; ochreous hematite; hornstone; serpentine; barite (!), granular, on Fox Branch, 10 miles below Asheville; on road to Burnsville, 14 miles north, chrysolite; 17½ miles north, hornblende; 19 to 20 miles north, pyrrhotite; magnetite; hematite; corundum with hornblende and culsageeite; serpentine; prochlorite; asbestus; actinolite: kaolin; jefferisite.

Big Ivy.—Genthite, with chrysolite.

Black Mountain.—Almandite garnet; cyanite at Bowlen's Pyramid.

Flat Creek.—Foliated graphite in gneiss.

New Found Mountains.—Biotite.

Balsam Gap mine.—Allanite (!); beryl; muscovite; biotite; albite; black garnet; columbite; tourmaline.

Cane Creek.—Calcite; gold; hematite; limonite.

Ivy River.—Chrysolite; chromite; hornstone; genthite; talc; asbestus; tremolite.

Brushy Mountain mine.—Muscovite; kaolinite; orthoclase; albite.

Ream's Creek.—Garnet, large crystals.

Burnet mine.—Muscovite; orthoclase crystals, large (100 to 1,000 pounds).

N. P. Watkins's.—Corundum; cyanite; muscovite; tourmaline; garnet.

French Broad River.—Six miles north of Asheville, meteoric iron (!).

Hominy Creek.—Biotite.

Pisgah Mountain.—Ten miles southwest of Asheville, meteoric iron (!).

Turkey Creek.—Limonite; magnetite; chlorite; talc.

Swannanoa Gap.—Corundum in cyanite (!); muscovite; 2 miles southwest from gap, limonite; hornblende, one-quarter mile northwest; tourmaline, one-quarter mile west.

Swannanoa River.—Near Asheville, meteoric iron (!) with troilite; actinolite; black hornblende; beryl; 7 miles above Asheville, hematite; 9 miles east of Asheville, serpentine.

George Alexander's.—At mica mine: beryl; muscovite; kaolinite.

Elsewhere.—Gold; tourmaline; massive, 6 miles south of Asheville and on French Broad, near Buck Shoal; garnet; hematite; galenite, at L. Fortune's; muscovite in many mica mines; beryl, blue; talc; columbite; garnet; menaccanite; bed of limonite, at Blackwell's, 12 miles west of Asheville; chrysolite; graphite.

BURKE.

Brindletown.—At Mills's gold mine, crystallized gold; tetradymite; montanite; brookite; anatase; rutile; zircon; malacon; cyrtolite; monazite; xenotime; samarskite; columbite; fergusonite; hydrofergusonite; adelpholite (?); menaccanite; hematite; magnetite; chromite; limonite; pyrite; titanite; cyanite; fibrolite; corundum; muscovite; vermiculite; enstatite; hornblende, green and black; steatite; tourmaline, green and black; orthoclase; albite; zoisite (?); garnet; actinolite; beryl; talc; asbestus; quartz, clear, smoky, and amethystine; psilomelane; arsenopyrite (?); allanite; thorite; diamond. (This list is furnished by W. E. Hidden, and includes all discoveries to the close of 1889.)

Bear's Knob.—Corundum with muscovite, 4 miles southeast.

Brown Mountain.—Platinum, on Gen. Hoke's farm; fluorite; limonite; magnetite; albite; kaolinite; gold, in placers.

Linnville Mountain.—Menaccanite; hematite; itacolumite (!); radiated pyrophyllite; limonite; graphite; meteoric iron.

Bridgewater.—Manganese garnet; gold.

Morganton.—Lead, 4 miles north; graphite, at Morganton and 6 miles south; corundum altered to muscovite; quartz crystals; titanite at Morganton Springs; pyrite; garnet; magnetite; chlorite (?).

Pax Hill.—Gold (!); galenite.

Scott's Hill.—Gold; silver; cerargyrite; psilomelane; zircon; pyrite.

Shoup's Ford.—Beryl; garnet; corundum, in part altered to fibrolite (!); gold; magnetite; menaccanite; cyanite; tourmaline.

South Mountains.—Quartz crystals, inclosing liquid (!); garnet in trapezohedral crystals (!); granular hornblende; graphite, 8 miles southeast of Morganton; at Col. Gaither's 12 miles south of Morganton, gold in veins and placers; beryl (!), yellowish green and deep green (aquamarine), 9 miles southeast of Morganton; tourmaline (!), 16 miles southeast of Morganton; 4 to 6 miles south of Morganton, serpentine; talc; chlorite; actinolite; hematite; magnetite; asbestus; magnesite; breunnerite; chrysolite; garnet; tremolite; corundum, on lands of North Carolina State Company; arsenopyrite.

Piedmont Springs.—Four miles west, tourmaline.

Glen Alpine Springs.—Talc.

White's Knob.—One mile south, yellow ocher.

Sugar Mountains.—Quartz crystals, with double terminations, etc.; asbestus; gold; rutile; magnetite; beryl.

R. Havenar's farm.—Tourmaline; muscovite.

J. Huffman's farm.—Beryl; epidote; actinolite.

Laurel road.—Nine miles from Morganton; garnets, large.

J. London's farm.—Epidote; garnet; pyrite; gold.

Tate's farm.—Gold in placers.

G. Deitz's farm.—Beryl; tourmaline; albite; sagenite.

Hildebrand's farm.—Sagenite; beryl; asbestus; rutile.

Van Horn's farm.—Quartz crystals, inclosing fluid; quartz crystals, with basal plane; quartz crystals, smoky; sagenite; garnet.

(The last eight localities are furnished by Humphreys.)

Elsewhere.—In the gold gravel and sands of the county occur gold; palladium (?); corundum; menaccanite; chromite; rutile; anatase; brookite (!); pyrope; zircon (!); epidote; tourmaline, black and green; fibrolite; xenotime (!); monazite (!); wolframite (?); limonite; magnetite; hematite.

CABARRUS.

Gold in many veins and placers; meteoric stone; sulphur; chalcopyrite; magnetite; limonite.

Daniel Barnhardt's farm.—Barnhardtite.

Barringer's mine.—Gold; arsenopyrite.

Boger's mine.—Tetradymite (!); chalcopyrite; azurite.

Concord.—Rose quartz; hyalite; agate (also at Harrisburg); chalcopyrite; malachite; gold; bornite; asbestus, in rose quartz; tourmaline; magnetite; galenite.

Cosby's mine.—Stilpnomelane (?); wolframite; scheelite (!); cuproscheelite; siderite; barite.

Cullen's mine.—Tetradymite (!); cuprite in cubes (!); pseudomalachite; scheelite (!); malachite, in part pseudomorphous after cuprite (!); azurite.

Flowe's mine.—Wolframite (!); rhombic tungstate of lime (!); scheelite (!); barite.

Near Gold Hill.—Manganese garnet; magnetite.

House's mill.—Hematite.

George Ludwick's mine.—Gold; arsenopyrite (!); tetrahedrite (!); scorodite (!); pharmacosiderite; olivenite; pyrite; chalcopyrite.

McMakin's mine.—Silver; argentite; galenite; sphalerite; proustite (?); tetrahedrite, var. freibergite (!!); pyrolusite; pyromorphite; barite; goslarite; rhodochrosite; magnesite; calcite; wad; barite; talc.

Harrisburg.—Quartz crystals; agate.

Phœnix mine.—Gold; tetradymite (!); in Orchard vein, barite; pyrite; chalcopyrite.

Love mine, North Barrier, Furness, Elwood, and *No. 3, a group of mines around Phœnix.*—Gold; pyrite; chalcopyrite.

Long's mine.—Gold; pyrite; chalcopyrite; galenite.

Crowell's mine.—Gold; pyrite; galenite.

Newell mine.—Gold; pyrite; chalcopyrite.

Pharr mine.—Gold, in veins and placers; pyrite; chalcopyrite.

Fisher mine.—Near Concord: gold; pyrite; chalcopyrite.

Blackwelder mine.—Gold.

Barrier mines.—North, Middle and South Barrier: Gold; pyrite.

California mine.—Gold; pyrite.

Pioneer mills.—Molybdenite; chalcocite; chalcopyrite; barnhardtite; molybdite; chrysocolla.

Reed's mine.—Gold (! !).

Troutman's mine.—Sphalerite; pyromorphite.

Union mine.—Copper in arborescent crystals (!) and plates; chalcocite; chalcopyrite; cuprite (!), in octrahedra; malachite, fibrous.

White's mine.—Chalcopyrite; aikinite (?).

Elsewhere.—Gold; pyrite; agate; barite; galenite; sphalerite; magnetite; steatite.

CALDWELL.

Baker's mine.—Galenite; serpentine; picrolite; chrysotile (!); chrysolite; pyromorphite; anglesite; cerussite; asbestus; marmolite; psilomelane; chromite.

Buffalo River.—At Patterson's mill: pyrite in quartz.

Lenoir.—Magnetite; native sulphur in quartz (!); psilomelane, 4 miles west; asbestus, 6 miles east; hornblende, 6 miles west; amianthus, 15 miles northwest.

King's Creek.—Asbestus; anthophyllite; steatite.

Puett's.—Kaolinite.

Little John mine.—Gold (!); galenite; graphite.

Miller's mine.—Gold; galenite; pyromorphite.

Fort Defiance.—Tourmaline; beryl; graphite; garnet.

Patterson.—Magnetite; hematite; menaccanite; compact serpentine.

Wilson's Creek, near mouth.—Serpentine; talc.

Upper Creek.—Gold; tourmaline; limonite.

Near Grandmother Mountain.—Gold in placers; pyrite; quartz.

Tuttle's mine.—Gold in placers.

Richlands.—Magnetite; hematite; chlorite; serpentine; talc; martite.

Middle Little River.—Limonite; paragonite (?); muscovite; hematite.

Lower Creek.—Gold, in the gravel of most of its tributaries below Lenoir.

Elsewhere.—Gold, in placers and veins; sulphur; cuprite; pyrite; quartz crystals; epidote; muscovite; orthoclase; cyanite; malachite;

tourmaline; paragonite (?), common in schists; muscovite; hematite; limonite; chlorite; tremolite.

CAMDEN.

Calcite in marl beds.

CARTERET.

Calcite in marl beds.

CASWELL.

Meteoric iron (!); garnet; magnetite; pyrite.

Leasburg.—Albite (?), 3 miles west of Leasburg; fibrous tourmaline (!); chlorite; epidote.

CATAWBA.

Ball Creek mine.—Magnetite; kaolinite.

Roberson mine.—Magnetite.

Abernathy mine.—Magnetite.

Littlejohn's mine.—Limonite; hematite.

Hickory.—Graphite, crystallized; pyrite(!); alunogen; wad; amphibole; hematite; pyrolusite; limonite; quartz crystals; amethyst(!); garnet(!); muscovite; pyrrhotite; magnetite; chalcopyrite; calcite and pyrrhotite near Hickory; graphite, 2 miles southwest.

Hooper's quarry.—Granular calcite; pyrite; gold; graphite; tremolite.

Newton.—Kaolin; magnetite, at the Barringer mines; pyrite; tabular quartz, 6 miles west and 10 miles northeast of Newton.

Keeversville.—Quartz crystals; muscovite.

Ramseur's.—Muscovite.

Powell's quarry.—Calcite, granular(!); pyrite.

Shuford's mine.—Gold; pyrite.

Shuford's quarry.—Calcite; magnetite; rose quartz; amethyst.

South Mountains.—Graphite; cyanite; garnet.

Anderson's Mountain.—Magnetite; calcite; at Avery Shuford's, actinolite.

Forney's mine.—Magnetite.

Beard's mine.—Magnetite.

Powell's factory.—Manganese garnet.

Elsewhere.—Gold, in placers and veins; graphite; rutile, in acicular crystals in amethyst(!); rock crystal(!); quartz crystals inclosing liquid(!); beryl(!); garnet(!); cyanite; kaolinite; alunogen; wad; rutile in quartz (sagenite), at D. Lutz's; beryl; paragonite (?), common in the schistose rocks.

E. Balch's farm.—Muscovite; garnets; amethyst; smoky quartz crystals containing liquid; crystals of quartz with basal plane; graphite; black and brown tourmaline; rutile (acicular); beryl (blue, green, yellow); feldspar.

H. Balch's farm.—Liquid-bearing quartz crystals; gold; sagenite.

Widow Balch's farm.—Sagenite; liquid-bearing quartz crystals, with basal plane; tourmaline; rose quartz.

Rev. Huffman's farm.—Tessellated quartz crystals; same, liquid bearing; menaccanite; sagenite.

Spencer's farm.—Quartz crystals doubly terminated; same, liquid-bearing; same, inclosing mica; same, with asbestus; same, with pyrite; rutile in quartz crystals; amethyst; cyanite; tourmaline; magnetite.

Near Canova.—Smoky quartz crystals, large; crystals of amethyst, doubly terminated, inclosing rutile (yellow).

CHATHAM.

Buckhorn.—Hematite, foliated, granular, and micaceous; magnetite; rutile in quartz; manganese garnet; muscovite; psilomelane; limonite; epidote.

Carbonton.—Pyrophyllite slate (!)

Clegg's mine.—Galenite; bornite; chalcopyrite; pyrite in cubo-octahedra; cuprite; chrysocolla; pseudomalachite (!); cerussite (!); malachite (!), fibrous and earthy; azurite; anthracite; calcite; galenite; prochlorite (?).

Deep River.—Pyrophyllite slate (!); anthracite; bituminous coal.

Egypt.—Siderite (black band and ball ore); dufrenite (!)

Evans's mine.—Hematite; chloritoid in pyrophyllite slate.

Unthank's mine.—Magnetite.

Farmville.—Siderite (!) (black band and ball ore); bituminous coal.

Gulf.—Siderite (black band and ball ore); bituminous coal; limonite.

Lockville.—One-half mile above Lockville, hornstone; 7 miles west of Lockville, foliated and micaceous hematite; 6 miles southeast of Lockville, fine granular and compact hematite; 4 miles southeast, garnet.

Kelly's ore bed.—Hematite (!)

Glass's mine.—Magnetite.

Pittsboro.—One-half mile west, kaolin; 6 miles south, on Rock Creek, chalcopyrite (!); at Gum Spring, limonite, pseudomorphous after pyrite; 7 miles west, kaolin; 10 miles southwest, micaceous hematite; 16 miles west (R. J. Powell's), hematite; magnetite.

Fearrington's mill.—Three miles west, hematite.

Lindley's mine.—Gold; pyrite; chalcopyrite.

Harper's Cross-Roads.—Kaolin.

Healy's Bridge.—One mile east, wad.

Ore Hill.—Hematite, compact, foliated, and micaceous; limonite (!); magnetite.

Cane Creek.—Gold, in veins; pyrite.

William's mine.—Galenite; chalcopyrite.

Battle's Dam.—Rose quartz; hematite; garnet; psilomelane.

Snipes's mine.—Magnetite; epidote; chrysocolla; azurite.

Danelly's Creek.—Gold; pyrite; chlorite.

Elsewhere.—Gold, in placers and veins; chalcopyrite, mouth of Rocky River; pinite; halite in brine; amethyst; kaolin; halloysite.

CHEROKEE.

Hanging Dog Creek.—Tourmaline; limonite; staurolite.

Marble Creek.—Tremolite; talc; calcite, (granular), white, pink, gray (!).

Murphy.—Galenite; pyrolusite; limonite (!); wad; tremolite; talc (!); cerussite; at Number Six mine, calcite; tremolite; gold; galenite (argentiferous).

Nantehalch River.—Niter in slates; calcite (!), granular, white, and pink; talc, massive white.

Parker mine.—Staurolite (!); gold; garnet.

Peachtree Creek.—Hematite; garnet; biotite; limonite; asbestus; red ocher; talc.

Valley River.—Hematite; phlogopite; talc; calcite (granular); dolomite; yellow ocher; limonite; gold, in placers; staurolite; corundum in cyanite, half way between Murphy and Valleytown.

Brasstown Creek.—Gold in veins and placers; calcite; limonite.

Notteley River.—Limonite; calcite; talc; staurolite; garnet.

Valleytown.—Rutile; at Whittaker's, brown ocher.

Number Six mine.—Tremolite; calcite.

Beaverdam Creek.—Smoky quartz (at mouth of Creek).

Elsewhere.—Gold in placers; cyanite, more or less altered to muscovite; staurolite (!); pseudomorphs of muscovite after staurolite. The staurolite localities are 11½, 15½, and 17 miles west of Murphy, and 11 miles from Ducktown, on the Morganton road.

CHOWAN.

Calcite, in marl beds.

CLAY.

Cullakenee mine, Buck Creek.—Corundum (!), white, gray, pink, and ruby, frequently altered into other minerals; spinel (!), rare; chromite (!) drusy quartz; black hornblende or arfvedsonite (!); smaragdite; chrysolite (!); zoisite (!); andesite (!); labradorite (!); orthoclase (!) tourmaline; serpentine, massive and variety picrolite (!); willcoxite; margarite (!!); talc; albite; cyanite; enstatite; augite (?); prochlorite.

Brasstown.—Micaceous hematite.

Shooting Creek.—Corundum (!); pseudomorphous quartz after feldspar (?); actinolite; chrysolite; talc; prochlorite; willcoxite (!); margarite; rock crystal; magnetite; cyanite; muscovite; gold in placers; rutile in black crystals; garnet; pyrite; chalcopyrite; micaceous hematite; limonite; prochlorite (?).

Tusquittah Creek.—Gold in placers and veins; staurolite; rutile.
Tipton's.—Corundum; cyanite (green); muscovite.

CLEVELAND.

Whiteside mine.—Gold in placers.
Mountain mine.—Rock crystal (!); tourmaline (!); garnets; gold in placers; graphite; arsenopyrite; galenite; muscovite (!); melanterite; alunogen; pyrite, abundant in gneiss and mica schists; tourmaline.
Cleveland Mills.—Two miles distant, limonite.
Shelby.—Within a few miles, muscovite in large plates; magnetite; actinolite; tourmaline.
Double Shoals.—Arsenopyrite.

COLUMBUS.

Calcite, in marl beds; near Whiteville, in crystals.

CRAVEN.

Calcite, in marl beds; glauconite, in greensand.

CUMBERLAND.

Petrified wood, Fayetteville; calcite, in marl bed; lignite, limonite.

CURRITUCK.

Calcite, in marl beds.

DARE—(None.)

DAVIDSON.

Cid mine.—Chalcocite.
David Beck's mine.—Tetradymite (!); montanite (!).
Boss's mine.—Galenite, coarse grained.
Conrad Hill.—Chalcopyrite; hematite; limonite; siderite; malachite; barite.
Allen mine.—Gold; pyrite; chalcopyrite; arsenopyrite; tetradymite.
Emmons's mine.—Chalcopyrite; pyrite.
Loftin mine.—Chalcopyrite; pyrite.
Miller's mine.—Sphalerite; chalcopyrite.
Harris's mine.—Gold; pyrite; chalcopyrite.
Moore's mine.—Galenite; pyrite; calcite.
Silver Hill.—Silver (!); argentite; highly argentiferous galenite (!); sphalerite (!); chalcocite; pyrite; chalcopyrite; cuprite; melaconite; zoisite (?); orthoclase (!); calamine; pyromorphite (!!); green, yellow, brown, black, and colorless; wavellite (!); stolzite (!); anglesite (!); goslarite; chalcanthite (!); calcite; cerussite (!!) in fine crystals, massive and in pseudomorphs after pyrite; malachite.

Thomasville.—Epidote; muscovite; biotite; magnetite; augite.
Silver Valley.—Galenite; sphalerite; pyromorphite.
Uharrie River.—Sphalerite.
Russell mine.—Gold; pyrite.
Ward's mine.—Gold; electrum(!); pyrite; chalcopyrite.
Delk mine.—Gold; limonite; hematite; pyrite.
Laughlin mine.—Gold; limonite; hematite; pyrite.
Miller mine.—Gold; pyrite; limonite; hematite.
Brown mine.—Gold; pyrite.
Midway.—Gold; pyrite; chalcopyrite; chalcedony; hornstone.
Lick Creek.—Meteorite.
Elsewhere.—Gold, in veins and placers; titaniferous magnetite.

DAVIE.

Magnetite; hematite, in several localities in beds; calcite, granular, on Yadkin river.

DUPLIN.

Calcite, in marl beds; limonite; glauconite; pyrite; lignite.
Near Magnolia, phosphatic beds.

DURHAM.

Durham.—Pyrite.
Near Knap of Reeds.—At James Woods's hematite (!); magnetite(!); steatite.
Red Mountain.—Epidote.

EDGECOMBE.

Vivianite, in marl; limonite; glauconite; pyrite; lignite; kaolinite, near Battleboro; calcite in marl beds; radiated and tabular quartz at Rocky Mount.

FORSYTH.

Plaff's quarry.—Calcite, granular.
Near Salem.—Magnetite, four miles south; manganese garnet; halloysite; hematite; micaceous hematite; graphite; emery variety of corundum; wad; halloysite.
Old Town.—Orthoclase; halloysite; asbestus; hematite; kaolin; talc.
Near Kernersville.—Enstatite, var. bronzite; chrysolite; tourmaline; magnetite; hematite; chlorite; pyrite.
Brookstown.—Calcite; tremolite.
Elsewhere.—Titaniferous magnetite (!); gold; also pure magnetite (!); serpentine.

FRANKLIN.

Portis mines.—Gold in placers (!); diamond (!); muscovite, in large plates; magnetite; asbestus; tabular quartz.

Franklin.—Kaolin.

Near Louisburg.—Halloysite; asbestus; tabular quartz.

Mann Arrington mine.—Franklinite (?).

Laurel.—Muscovite.

GASTON.

Asbury's mine.—Silver; tetradymite; galenite; pyrrhotite; pyrite; leucopyrite; auriferous arsenopyrite; bismite; scorodite; montanite (?); cerussite; bismutite (!).

Cansler and Shuford mine.—Gold (!); galenite.

Clubb's Mountain.—Corundum, red and blue (!), also mammilary (Dr. Hunter); rutile (!!); tourmaline, granular and fibrous; leopardite; cyanite (!); pyrophyllite (!); muscovite (!); lazulite (!); talc; quartz crystals; margarite; hematite; muscovite; manganese garnet; magnetite; gold; iron garnet.

Clear Mountain.—Lazulite.

Crowder's Mountain.—Corundum, red and blue (!), also variety emery; rutile (!); in crystals and granular; gold; menaccanite; cyanite (!); topaz (?); pyrophyllite (!); muscovite (!); monazite; lazulite (!); barite, with galenite (argentiferous); hematite; limonite; sphalerite; tourmaline; pyrite; chalcopyrite; manganese garnet; pyromorphite.

Yellow Ridge.—Magnetite.

Stowe's Factory.—Magnetite.

Sloan mine.—Gold; pyrite.

Beck's.—Pyrolusite; manganese garnet; psilomelane.

High Shoals.—One mile above, granular calcite.

Ellison ore bank.—Hematite; magnetite; chlorite; orthoclase; epidote; tourmaline.

Ormond ore bank.—Limonite, compact and fibrous; psilomelane, nickeliferous.

Mountain mine.—Hematite, mammilary and cellular; pyrolusite; quartz.

King's Mountain.—Gold; galenite; altaite; chalcopyrite; sphalerite; tetrahedrite; nagyagite; magnetite; bismite; calcite; dolomite; pyrrhotite; chalcopyrite; limonite; barite; pyrite; graphite; cassiterite.

Long Creek mine.—Nickeliferous psilomelane (!); gold; pyrite; fluorite; sphalerite; mispickel; galenite.

Duffie mine.—Gold; pyrite; chalcopyrite; also at B. Wells's mine.

Oliver mine.—Gold; silver; galenite.

White's mills.—Epidote; biotite; orthoclase (!); pycnite; titanite.

Wells's farm.—Magnetite; hematite; pyrite; rutile; garnet; zircon (?); beryl; tourmaline; monazite; asbestus; menaccanite; azurite; bornite (?).

Rhodes's mine.—Epidote; actinolite; gold.

Ferguson mine.—Magnetite; pyrite.

All-Healing Springs.—Barite.

Elsewhere.—Sulphur; pyrite; magnetite; calcite; siderite; gold in placers and veins, at the Dew, Smith, Farrar, Beattie, McLean, High Shoals, and Cannon mines.

GATES.

Calcite, in marl beds.

GRAHAM.

Gold; calcite, granular, white, and flesh-colored; talc; pyrite.

GRANVILLE.

Young's Cross Roads.—Gold; pyrite; two miles southeast, malachite.

Near Oxford.—Magnetite; limonite; epidote; hematite; gold; lignite on Tar River, near Crews's.

Patterson mine.—Native copper.

Grissom.—Enstatite.

Bowling's Mountain.—Radiated pyrophyllite.

Sassafras Fork.—Gold; pyrite; a few miles north, malachite; tourmaline; quartz crystals; agate.

Near Shiloh Church.—Epidote; labradorite; calcite.

Elsewhere.—Stibnite, in the northern part of the county, on land of N. A. Gregory.

GREENE.

Limonite; siderite; glauconite; calcite in marl.

GUILFORD.

Cambridge mine.—Chalcocite; pyrite (!); chalcopyrite; barnhardtite; chrysocolla; malachite.

Fisher Hill.—Gold; pyrite; chalcopyrite; magnetite; hematite; menaccanite; limonite; pseudomalachite; siderite.

Beard mine.—Gold.

Friendship.—Granular corundum (emery); titaniferous magnetite.

Gardner Hill.—Bornite (?); chalcopyrite; chrysocolla; malachite.

Greensboro.—Hornblende, at Polecat Creek; pyroxene; pyrite; five miles west, gold; pyrite; chlorite; nine miles south, kaolinite, and also six miles west.

High Point.—Graphite; talc; chalcopyrite; orthoclase.

McLeansville.—Asbestus (?) in green quartz.

Near Alamance Church.—Kaolinite.

McCulloh mine.—Copper; cuprite in acicular crystals (!); pyrite; chalcopyrite; siderite; malachite.

Near Jamestown.—Gold; pyrite; steatite.

North Carolina (Fentress) mine.—Cuprite in acicular crystals (!); pyrite; chalcopyrite; siderite; malachite.

Phœnix mine.—Chalcopyrite; covellite.

Elsewhere.—Gold in veins; meteoric iron; molybdenite; limonite; rock crystal; pyrite; manganese garnet; magnetite; asbestus in green quartz (!), (Humphrey's); titaniferous magnetite, with hematite and limonite, chlorite, in a double range of outcrops of 20 miles length across the northwest section of the county, from the head of Deep River, on the Forsyth line, to the Rockingham line, near the Piedmont railroad at Haw River; kaolin at C. S. Leonard's, in the southern part of the county.

HALIFAX.

Near Ransom's Bridge.—Gold in placers; pyrite.

Fishing Creek.—Magnetite crystals and cubical pyrite in slate.

Gaston.—Hematite, micaceous and granular; magnetite; chlorite; limonite; 6 miles south, Hines's place, hematite; magnetite.

Elsewhere.—Petrified wood; epidote; zircon and garnet, in gold gravels; calcite and glauconite in marl; apatite; epidote.

HARNETT.

Harrington.—Calcite, granular.

Near Buckhorn.—Hematite; rutile in quartz; epidote; prochlorite (?).

Northington's Dam.—Chrysocolla; calcite, in gneiss rock.

Little River.—Magnetite, several places.

Douglass ore bed.—Magnetite.

Chalk Level.—Limonite (bog ore).

Hector's Creek.—Smoky quartz.

Elsewhere.—Talc; magnetite; kaolin, abundant at Spout Springs and at several other places.

HAYWOOD.

Big Ridge mine.—Muscovite; biotite; tourmaline; apatite; menaccanite; albite; autunite; kaolin.

Waynesville.—Corundum; two miles above, talc; asbestus; tremolite; on Richland creek, 2 miles below, psilomelane; garnet; limonite; muscovite; cyanite; 4 miles south, menaccanite.

Hall's mine.—Chrysolite; corundum; talc; chlorite; tremolite.

Presley mine.—Corundum, blue and gray, altered into muscovite and albite; albite; muscovite in large crystals, also in scales cryptocrystalline and compact.

Wilkins's Creek.—Magnetite with limonite; chalcopyrite; pyrite.

Cove Creek.—Psilomelane; limonite.

Pigeon River, east fork.—Corundum; pyrrhotite; wad.

Pigeon River, west fork.—At Sorrell's mine, nickeliferous (?) pyrrhotite.

Upper Pigeon Valley.—Graphite.
Ground Hog Creek.—Galenite.
Jonathan's Creek.—Cyanite; pyrrhotite; graphite; garnet.
Ruce's mine.—Opalescent quartz; pyrite; garnet.
Springdale.—Melanterite; pyrite.

HENDERSON.

Coleman's Station.—Zircon; phlogopite; jefferisite.
Green River.—On south side of Blue Ridge, at Freeman's, zircon; xanthitane; calcite, granular; titaniferous garnet at Jones's mine; auerlite; on Price's farm, zircon; auerlite; on the Davis land, polycrase; zircon; monazite; xenotime; cyrtolite; magnetite.
Elsewhere.—Beryl; limonite; hematite; vermiculite; meteoric iron.

HERTFORD.

Calcite, in marl beds.

HYDE—(None.)

IREDELL.

Belt's Bridge.—Pyrite in soapstone; corundum (!) in globular masses, partly altered into muscovite, etc.; near Belt's Bridge, limonite; Hendrick's farm, corundum in hexagonal crystals (!) partly altered into margarite; orthoclase; tourmaline; muscovite (!) soda-margarite at Hendrick's farm.
Center Point. At Beam's farm; limonite (!) pseudomorphous after nodular pyrite.
Crawford's farm.—Quartz pseudomorphous after calcite.
Damascus.—Menaccanite.
Dr. Halyburton's.—Leucopyrite (!); scorodite.
King's Mill.—Graphite (!); hematite in hexagonal plates in quartz; rutile (!), in quartz, at Mrs. Jordan's, Alex. Lackey's, Misses Bennett's, Thomas Adams's and Mrs. Smith's farms; rock crystal (!); quartz crystals inclosing liquid (!); chalcedony; tourmaline (!).
Mount Pisgah.—Rutilated quartz (!) at Mrs. Daniel's farm; chloritic mineral resembling thuringite.
Rocky Creek.—Graphite.
Spring Mountain.—Graphite (!).
Statesville.—Near Statesville, titanite in gneiss; quartz crystals; 6 miles north, allanite; 8 miles southeast, on road to Salisbury, tremolite; 2 miles west, corundum (!), rarely altered into cyanite (!); orthoclase (!) on Houp's farm; cyanite (!), 2 miles west and 6 miles southwest of Statesville on Hoover's farm, with muscovite (!); 4 miles distant, goethite in thin scales, in light red feldspar (sunstone); 5 miles west, on John Sumpter's farm, rutile; zircon; cyanite; transparent ripidolite. 7 miles north, on farm of G. W. Chipley, near South Yadkin River, gray corun-

dum in crystals. At Statesville rock quarry, sunstone; titanite; hornblende in large crystals.

Bethany Church.—Allanite, with small crystals of zircon: above Lock's Bridge, corundum altered into prochlorite and margarite.

Hunting Creek.—Albite; blue corundum altered into rhaetizite. On Sale's farm, near Campbell's Mill, large bowlders of cyanite inclosing crystals of blue corundum.

Near Shiloh Church.—Red ocher.

Near Holland Springs.—Quartz crystals.

Davidson Township.—Quartz, inclosing transparent red goethite.

Rockwell.—Smoky quartz.

Elsewhere.—Marcasite; magnetite near Comb's, and on South Yadkin River.

JACKSON.

Casher's Valley.—Bismutite; talc; muscovite; amethyst; rock crystal; gold; pyrite; chalcopyrite.

Cullowhee mine.—Chalcocite; pyrite; melaconite; chalcopyrite (!); hornblende; malachite.

Hogback mine.—Corundum (!); rutile in corundum, rare; chromite; drusy quartz; chrysolite (!); andesite (!); tourmaline; muscovite (!); dudleyite; margarite (!).

Savannah mine.—Chalcopyrite; hornblende; tourmaline; malachite.

Horse Cove.—Muscovite; beryl.

Tennessee Creek.—Tremolite; grammatite; chlorite; actinolite; talc; asbestus; prochlorite (?).

Whiteside Mountain.—Garnet; orthoclase; tremolite; actinolite; chalcopyrite; magnetite; asbestus; muscovite; biotite; wad.

Balsam Mountain.—Tourmaline; pyrolusite; chalcopyrite.

Waryhut mine.—Chalcocite; chalcopyrite; cuprite; malachite.

Georgetown and Fairfield.—Gold in placers.

Webster.—Corundum; chromite; pyrolusite; wad; chalcedony; drusy quartz; enstatite (!); tremolite (!); actinolite (!); asbestus; chrysolite (!); talc (!); serpentine; marmolite; deweylite; genthite; penninite (!); magnesite (!), crystalline and earthy; magnetite; kaolin; kämmererite; 6 miles north, chrysolite and enstatite; 10 miles west, hornblende.

Wolf Creek mine.—Chalcocite; native copper; chrysocolla; chalcopyrite; malachite.

Ainslie's.—Chrysolite; chromite; talc; chlorite; enstatite; smaragdite (?); asbestus; tremolite; garnet; actinolite; albite.

Scott's Creek.—Chrysolite; chromite; talc; penninite (var. kämmererite); enstatite; chlorite; corundum (blue and pink).

Toxaway River.—Calcite, granular.

Elsewhere.—Gold in placers; psilomelane; calcite; asbestus; talc; limonite; muscovite in many mica mines; galenite; at Bryson's and in Hogback Valley, hematite; at Dr. Morgan's, psilomelane.

JOHNSTON.

Elevation.—Clay ironstone; pyrite.
Leechburg.—Limonite.
Near Clayton.—Chloritic talc slate; graphite; kaolin.
Near Princeton.—Epidote.
Near Smithfield.—Limonite in many places.
Elsewhere.—Fossil wood; kaolinite; magnetite; pyrite; tourmaline; graphite; epidote; muscovite; quartz crystals; hematite.

JONES.

Calcite, in marl beds; limonite.

LENOIR.

Calcite, in marl beds; glauconite, in green sand marl.

LINCOLN.

Lincolnton.—Calcite; 12 miles northwest, reticulated acicular rutile; halloysite; kaolinite; graphite; limonite, 7 miles northwest and 2 miles east; on land of S. W. Childs, arsenopyrite.
Brevard's Forge.—One and one half miles from Vesuvius furnace, magnetite (!); manganese garnet; quartz crystals.
Cottage Home.—Diamond (!); gold; chalcopyrite.
Macpelah Church.—Manganese garnet; psilomelane; pyrite and chalcopyrite, 2 miles east.
Graham mine.—Chalcopyrite; gold.
McBee's.—Psilomelane.
Keener's quarry.—Chalcopyrite; bornite.
Iron station.—Vivianite.
Randleman's.—Quartz crystals; amethyst (!).
Stowe's quarry.—Calcite, granular and compact.
Elsewhere.—Gold in placers and veins; sulphur; graphite; hematite; magnetite; limonite; muscovite; kaolinite; epidote; pyrite; calcite, near Lincolnton (!); asbestus; chalcedony; garnet; psilomelane; talc; cuprite; cyanite, blue and red; galenite; graphite; limonite; menaccanite; actinolite.

MACON.

Houston's mine.—Muscovite; corundum: talc; tremolite; chlorite; tourmaline.
Lyle's mine.—Muscovite; biotite; kaolinite.
J. Moore's.—Chromite; corundum.
Thorn Mountain mine.—Muscovite; biotite; manganese garnet; albite; uranochre (?); zippeite (?); beryl; pyrrhotite; chalcopyrite.

Culsagee mine or Corundum Hill.—Corundum (!) in beautiful varieties crystallized and massive, and frequently in part altered into other minerals; chromite (!); spinel (!) in crystals and granular; rutile (!), rare; diaspore (!), one specimen only known; drusy quartz (!) and quartz crystals; chalcedony; hyalite (!); enstatite (!); tremolite; arfvedsonite (!); chrysolite (!); andesite (?); oligoclase; tourmaline (!); talc; serpentine (!); deweylite (!); cerolite; genthite (!); culsageeite (!); lucasite; kerrite (!); maconite (!); penninite (!); prochlorite (!); willcoxite (!); margarite (!); anthophyllite; actinolite; magnetite.

Bryson's mines.—Muscovite (!); labradorite; almandite garnet; orthoclase; albite; biotite.

Near Franklin.—Sphalerite; chalcopyrite; menaccanite (!); wad; garnet (!); epidote (!); fibrolite (!); cyanite (!); staurolite (!); kaolinite (!); rhodochrosite; corundum; pyrite; 7 miles south, chromite, chlorite; 9 miles south, chrysolite; 11½ miles south, prochlorite; 14 miles south, corundum and talc in chrysolite.

Highlands.—Bismutite; beryl.

Haskett's.—Limestone quarry; magnetite; corundum (!), in part altered into muscovite; tourmaline; calcite; garnet; molybdenite.

Jacob's mine.—Corundum; asbestus; tremolite; chrysolite.

Sugartown Creek.—Chromite; tremolite; actinolite; asbestus: chrysolite; garnet; biotite; orthoclase; magnetite; hematite; 8 miles from Franklin, prochlorite; talc; asbestus.

Nantehaleh River.—Asbestus; talc (!); compact limestone (!); niter; at mouth of river, orthoclase.

Tennessee River, below Franklin.—Garnet; staurolite; cyanite; muscovite; columbite.

Tibbet's mine.—Pleonaste; zircon.

West's mine.—Ruby corundum with cyanite.

Gregory Hill.—Chrysolite; anthophyllite; bronzite; foliated talc; prochlorite; asbestus.

Hall mine.—Muscovite (!); biotite; granular quartz; orthoclase; garnet; albite.

Rocky Face.—Garnet; muscovite; biotite.

Jarrett's.—Steatite; chalcedony; fibrous talc.

Potato Knob mine.—Mucovite; biotite.

West's Mills.—Psilomelane.

Ellijay Creek.—Near Higdon's: corundum; chlorite; asbestus; chromite; magnetite; hematite; garnet; chrysolite. At Goshen, calcite, granular; coccolite; graphite; spessartite.

Highlands.—Gold; rose quartz.

Catoogajay Creek.—Magnetite, at Sloan's.

Elsewhere.—Graphite; garnet; chalcopyrite; magnetite; hornblende, 23 miles below Franklin; beryl; rose quartz; magnetite; muscovite and biotite in numerous mica mines; gold and galenite in Cowee Mountains.

MADISON.

Bear Creek.—Magnetite (!), 2 miles from mouth; green coccolite, in granular calcite; chlorite; epidote; cyanite; staurolite; talc; garnet, (large crystals); 1 mile from mouth, tremolite; hornblende; 1½ miles from mouth, chrysolite; magnetite.

Mars Hill.—Monazite; zircon.

Big Laurel.—Magnetite (!); menaccanite (!); milky quartz; pyrite; calcite, granular, and massive.

Carter's mine.—Corundum (!!) in peculiar white and pink varieties; spinel (!); chromite; hornstone; drusy quartz; tremolite; chrysolite (!); andesite (!); prochlorite (!); culsageeite; menaccanite; beryl (!).

French Broad River.—Orthoclase; calcite, with coccolite; limonite, in a heavy bed, near State line.

Duel or Jewell Hill.—Meteoric iron (!); ferrous chloride in meteorite; hematite.

Near Marshall.—Calcite; pyrite; rutile; limonite; magnetite (!); galenite; bornite; chalcopyrite; epidote; talc; fluorite; hematite, near Gudger's, 9 miles below Marshall; corundum (!), 3 miles below Marshall; diaspore (!); prochlorite (!); margarite; barite, at Chandler's, 9 miles below Marshall; 4 miles west of Marshall, smoky quartz, in doubly terminated crystals; 1 mile below Marshall, agate; hornblende; 3 miles below, augite (!); 6 miles below, penninite; orthoclase; 8 miles below, epidote; orthoclase; 9½ miles below, penninite; orthoclase; 4 miles up Ivy Creek, hornblende.

Walnut Creek, near French Broad River.—Green coccolite, in calcite; phlogopite.

Hot Springs.—Cryptocrystalline muscovite (!); calcite; red jasper; pyrite; psilomelane; gold, in veins and placers; garnet.

Shut In Creek.—Calcite; jasper.

Spring Creek.—Magnetite, in large bed, massive.

Ivy River, two miles from mouth.—Smith mine: magnetite; pyroxene. At Radford's, hematite and magnetite.

Brush Creek.—Magnetite, at Freeman's and Sikes's; coccolite in calcite; barite.

Paint Creek.—Pyrrhotite.

Haynie mine.—Blue corundum; rutile; margarite; green crystals of hornblende; magnetite; chlorite; menaccanite.

MARTIN.

Calcite, in marl beds.

M'DOWELL.

Cave of Tantalus.—Stalactitic calcite.

Humpback Cave.—Stalactitic calcite.

Cedar Cove, at Dodson's mine.—Sphalerite; calcite, granular and compact.

Kirksey's mine.—Tetradymite.

Linville Mountains.—Itacolumite; radiated pyrophyllite; limonite, in many places; hematite; calcite, granular and compact, several places; meteoric iron.

Peter's Cove.—Stalactitic calcite; magnetite; limonite.

Turkey Cove.—Calcite, granular and compact.

Turkey Creek.—Bee Rock: epidote (!); tourmaline.

In the gold placers.—Gold; corundum; menaccanite; rutile; chromite; brookite; pyrope; zircon (!); epidote; fibrolite; xenotime (!); monazite (!); diamond; anatase.

Marion.—Within a few miles, limonite; manganese garnet; psilomelane; calcite.

Raccoon Cave.—Stalactitic aragonite.

Round Knob.—Cyanite; garnet; paragonite.

Graveyard Mountain.—Hematite; limonite; calcite.

Head of Tom's Creek.—Magnetite; muscovite; kaolinite.

Elsewhere.—Limonite; calcite; samarskite; dolomite, one-half mile east of Yancey's mine.

MECKLENBURG.

Beattie's Ford.—Rutile (!) in acicular crystals.

Capp's Hill.—Magnetite; gold; pyrite; chalcopyrite.

Charlotte.—Orthoclase var. leopardite (!); at the Rudisill mine, gold-bearing pyrite; chalcopyrite; white siderite; 2 miles from Charlotte, pyrite; chalcopyrite; magnetite, fine granular; at new cemetery, epidote.

Davidson College.—Radiated cyanite; pyrophyllite; gold; agate, 5 miles south at D. Caldwell's; hematite at Gibson's, 5 miles from Davidson College; 7 miles south, fine crystals of rutile; 12 miles southwest, granular hematite.

Hopewell mine.—Chalcopyrite; chrysocolla; pyrite; gold.

McGinn mine.—Gold; pyrite; chalcopyrite; barnhardtite; cuprite in acicular crystals; melaconite; pseudomalachite (!).

Old Harris mine.—Hematite; menaccanite.

Providence.—Twelve miles south of Charlotte, chalcopyrite; gold; pyrite; magnetite.

Todd's Branch.—Gold; diamond (!); zircon (!); garnet; monazite (!).

Tuckasegee Ford.—Epidote; labradorite near Tuckasegee Ford.

Stephen Wilson's mine.—Gold; pyrite; chalcopyrite; siderite.

Gibson mine.—Gold; also at Jordan mine, Brown mine, Carson mine, Icyhour mine, Burnett mine, Neal mine, Brawley's mine.

Roswell mine.—Gold; pyrite; also at Stearne's mine, Roger's mine, Stinson mine, Crosby mine, Johnson mine, Juggernaut mine, Frazer mine, Taylor mine, Maxwell mine, Nolen mine, Crump mine, Bane mine, McCorcle mine, Hunter mine, Henderson mine, Alexander mine, J. Alexander's mine, Caldwell mine, Davidson and Blake mine.

Sugar Creek.—Magnetite.

Faire's mine.—Gold; pyrite chalcopyrite.

Frederick mine.—Gold; pyrite; chalcopyrite; chrysocolla; malachite.

Maxwell mine.—Gold; pyrite; chalcopyrite; also at Clark's mine, Ray mine, Hipp mine, Trotter mine, Harris mine, Henderson mine, Kern mine, Cathey mine, G. C. Cathey's mine, Sloan mine, McLean mine, Charlotte mine, and Queen mine.

Steele Creek.—Pyrolusite.

Elsewhere.—Gold, in placers and veins; copper in quartz crystals; sulphur; magnetite, near Steele Creek Church; foliated hematite at Sol. Reid's; tourmaline.

MITCHELL.

Bailey mine.—Orthoclase; hyalite.

Toe River Ford.—Actinolite, large crystals in talc; muscovite.

Bakersville.—Muscovite; chalcopyrite; pyrite; 2½ miles south, pyrophyllite; chromite(!); saponite; quartz crystals; chalcedony(!); enstatite(!); tremolite; actinolite; chrysolite(!); talc; rutile, penetrating corundum; serpentine; deweylite; penninite(!); magnesite; 1½ miles southeast, asbestus; talc; limonite; corundum; 2 miles southeast, limonite; psilomelane; 3½ miles north, apatite; at Hawk mine, oligoclase(!); on Yellow Mountains, cyanite(!).

Blalock's.—Garnet; muscovite(!); orthoclase(!); kaolinite; columbite.

Buchanan mine.—Gummite; yttrogummite(?); asbestus; beryl; allanite(!); muscovite(!); albite(!); phosphuranylite(!); cyanite; graphite; manganese garnet; black garnet; magnetite; limonite; apatite; orthoclase.

Cane Creek.—Menaccanite(!); actinolite; talc; asbestus; near head, graphite; rutile; garnet; samarskite.

Crab Orchard.—Menaccanite(!).

Autrey's.—On Brush Creek: quartz crystals, smoky; black garnet; kaolinite.

Cranberry.—Magnetite(!); pyroxene; epidote; picrolite; 1 mile west, hematite; orthoclase.

Plum Tree Creek.—Corundum crystals; hyalite.

Roan Mountain.—Hornblende.

Near White Plains.—Gummite with uraninite in a mica mine.

Deake mine.—Quartz, flattened out between muscovite; muscovite(!); columbite(!); gummite; albite; gahnite; monazite.

Flat Rock.—Menaccanite(!); uraninite(!); gummite(!); zircon; garnet; epidote; zoisite, var. thulite(!); muscovite(!); pink muscovite(!); albite(!); orthoclase(!); uranotil(!); phosphuranylite(!); autunite(!).

Grassy Creek.—Samarskite; menaccanite; kaolinite; beryl, large muscovite; autunite; hyalite; columbite.

Point Pizzle.—Albite(!); apatite(!); pyrophyllite; actinolite; beryl; garnet; manganese garnet; muscovite.

Old Fields of Toe.—Miller's Gap: epidote; talc; chlorite.

Unaka Mountains.—Magnetite (!); zircon (!); epidote; hematite.

Wiseman mine.—Muscovite (!); kaolinite; hatchettolite (!); columbite (!); samarskite (!); altered samarskite; rogersite; epidote; garnet.

Gillespie Gap.—Psilomelane; monazite; epidote; chalcopyrite; one-half mile west, prochlorite; psilomelane.

Burnsville.—Six, 13, and 14 miles north, labradorite in trap; 14½ miles north, prochlorite; culsageeite (?); asbestus; actinolite; tremolite.

Pumpkin Patch Mountain.—Magnetite; labradorite; garnets.

Burlison's.—Asbestus; actinolite; talc.

Lick Ridge mine.—Muscovite; albite; garnet, red and black; biotite; pyrite; chalcopyrite; hyalite.

Cox mine.—Smoky quartz; manganese garnet; albite; autunite; muscovite; biotite; apatite; labradorite; pyrite; orthoclase (?).

Eagle Mine.—Kyanite; muscovite; orthoclase; albite.

Gibbs's Mine.—Muscovite.

North Toe River.—Orthoclase; muscovite; chrysolite; talc; chrysotile; asbestus; prochlorite; wad; garnet; serpentine; 2½ miles northeast, kaolin; chalcedony.

Young's.—On South Toe River; serpentine; garnet; talc; chrysolite; prochlorite; tremolite; pyrite.

Elsewhere.—Galenite (!); rutile; garnet; epidote; fergusonite; actinolite (S. Blalock's); rock crystal; muscovite; kaolinite in numerous mica mines; corundum, 1 mile from Stewart's.

MONTGOMERY.

Cheek's Creek.—Fossil wood.

Cottonstone Mountain.—Pyrophyllite (!!)

Crump Mine.—Gold (!) in placers.

Christian mine.—Same as Swift Island.

Steele mine.—Gold (!!); galenite; sphalerite; chalcopyrite; albite; prochlorite; calcite.

Burnett Mountain.—Gold in placers.

Swift Island mine.—Gold (!!) in fine crystals.

Beaver Dam mine.—Gold in placers.

Elsewhere.—Gold in viens and placers; argentite in slates; magnetite; 5 miles above mouth of Uwharie River, hematite; ferruginous quartz.

MOORE.

Carthage.—Twelve miles east: hematite.

Cheek mine.—Chalcopyrite; malachite; azurite; galenite; red jasper; epidote; talc; calcite; argentite; pyroxene; limonite.

Jonesboro.—Two miles south, on Cane Creek; malachite.

Swan's Station.—Kaolin.

Sanford.—Pyrite; gold.

Johnson's mills.—Tourmaline; acicular horneblende in quantity.

Soapstone Quarry.—Slaty pyrophyllite (!); pseudomalachite.

Upper Little River.—Cyanite.

Welch's.—Chrysocolla; chlorite.

Elsewhere.—Gold in veins and placers; pyrite; fossil wood; at E. Kelly's, limonite; magnetite; enstatite; wad; at P. Martin's, agate; at J. Dunlap's, quartz crystals; at Johnson's mill.

NASH.

Battleboro'.—Kaolin.

Tom Arrington mine.—Gold in placers.

Mann mine.—Gold in placers; psilomelane.

Elsewhere.—Gold in placers; meteoric stone, near Castalia; crocoite (!); hematite; limonite; calcite, in placers; in Stony Creek township, chalcedony.

NEW HANOVER.

Calcite (!), granular and crystalline; lignite; glauconite; limonite; phosphatic nodules (!) in limestone at Castle Hayne.

NORTHAMPTON.

Calcite, in marl beds.

ONSLOW.

Calcite and phosphatic nodules (!) in marl.

ORANGE.

Aaron's Creek.—Jaspery quartz; radiated pyrophyllite (!).

Chapel Hill.—Hematite (!); limonite; epidote; near Chapel Hill, chalcopyrite; pyrite; magnetite; serpentine; hematite, pseudomorphous after pyrite; 4 miles west, limonite after pyrite; 7 miles west; pyrophyllite.

Hillsboro.—Pyrite in cubes; wad; limonite; hematite; pyrophyllite (!); chlorite in fine scales; epidote; barite (!), at Latta mine; brannite (!); hematite, 6 miles south; pyrite; chalcopyrite; 5 miles southeast, magnetite.

Eno River.—Serpentine; steatite.

University Junction.—Hornblende; hematite.

Elsewhere.—Halite in brine; micaceous hematite at Flat River and Elleby Creek; epidote; hematite, pseudomorphous after pyrite; serpentine; moss agate, slaty pyrophyllite.

PAMLICO.

Calcite, in marl beds.

PASQUOTANK—(None).

PENDER.

Calcite; glauconite; limonite; phosphatic beds; at Rocky Point, phosphatic nodules in limestone.

PERQUIMANS—(None).

PERSON.

Mount Tirzah.—Hematite, micaceous; menaccanite.
Barnett Mountain.—White cyanite (!).
Dillahay's mine.—Gold; radiated quartz.
Gillis mine.—Chalcocite; pyrite; covellite; micaceous hematite; chrysocolla; cuprite; malachite; calcite; garnet; quartz; epidote.
Leasburg.—Tourmaline; 3 miles north, albite (!).
Hico.—Felsite; graphite.
Roxboro.—Epidote in granite.
Mill Creek.—Chalcocite; chrysocolla.
Harris's mine.—Copper in epidote.
Woodsdale.—Gold in vein; pyrite.
Elsewhere.—Graphite, on Cane Creek; limonite; steatite; talc; hematite; magnetite; on W. A. Gillis's farm, chrysolite.

PITT.

Calcite; glauconite; siderite; limonite, in beds near Tranter's Creek; succinite.

POLK.

Sandy Plains.—At Davis's mine: gold; limonite; pyrite. At Morris's mine: gold; monazite; pyrite; epidote; asbestus; tourmaline. At Prince mine: monazite; rutile; zircon.
Morrill Mills's gold mine.—Euclase (!).
Hungary River.—Gold, in placers.
Pacolet River.—Gold, in placers.
Tryon Station.—Garnet; tourmaline.
Tryon Mountain.—Asbestus.
Elsewhere.—Gold in placers; monazite; xenotime; rutile; epidote; quartz crystals; manganese garnet; turgite.

RANDOLPH.

Near Ashboro.—Pyrophyllite.
Franklinsville.—Five to 7 miles west-northwest, leucopyrite.
Pilot Klob.—Pyrophyllite (!); gold, in placers; acicular rutile in quartz.
Hoover Hill mine.—Gold; galenite; calcite.
Kinley mine.—Gold; pyrite.
Jones mine.—Gold; pyrite; limonite.

Parish mine.—Gold; talc; tremolite; actinolite.

Elsewhere.—Gold in veins and placers; meteoric iron (!); magnetite; siderite; hematite (micaceous).

RICHMOND.

Rockingham.—Eight miles southeast: kaolin.

Hitchcock Creek.—Orthoclase (!); oligoclase.

Hamlet.—Kaolinite.

Elsewhere.—Pyrophyllite, in quartz schists; chlorite; on Yadkin River, 7 miles above mouth of Little River, calcite and shell limestone.

ROBESON.

Calcite, in marl beds; near Maxton, kaolin.

ROCKINGHAM.

Madison.—Chalcopyrite at W. Lindsay's; manganese garnet.

Leaksville.—Semi-bituminous coal.

Meadows.—Bog iron ore.

Smith's River.—Two miles east of Morehead's factory: hematite; gold; asbestus.

Troublesome Creek.—Magnetite; hematite; limonite.

Smith's Mountain.—Meteoric iron (!!) with schreibersite and ferrous chloride. Also on Deep Spring farm.

Reidsville.—Muscovite; near Reidsville, halloysite; 6 miles north, magnetite.

Wentworth.—Asbestus; near Wentworth, tourmaline; one-half mile south, pyroxene and tourmaline.

Elsewhere.—Halite in brine; titaniferous magnetite (!); garnet; cyanite; on Dan River, 4 miles above Town Fork, hornblende.

ROWAN.

Gold Hill.—Gold (!); bismuthinite; pyrite; chalcopyrite; arsenopyrite (!) at Honeycutt's; magnetite.

Salisbury.—Orthoclase (!); 7 miles south, Gold Hill road, pyrite; chalcopyrite; chrysocolla; talc.

Yadkin mine.—Gold; pyrite.

Dunn Mountain mine.—Gold; pyrite; chlorite.

Snider mine.—Gold; pyrite.

Grupy mine.—Chalcopyrite; pyrite; chrysocolla.

Cope mine.—Gold; also at Haynes mine, Cady mine, Bringle mine, Trexler mine, Yadkin mine, Bane mine, Roseman mine, Earnhardt mine, Holtshauser mine, in veins and placers.

Rhymer mine.—Gold; pyrite; hematite.

Elsewhere.—Orthoclase, in large and twin crystals; gold; pyrite.

RUTHERFORD.

Brindletown Creek.—Diamond (!).

Jeanstown.—Platinum; palladium (?); at Weaver's, garnet; epidote; tourmaline; gold; manganese garnet.

Laurel Springs.—Garnets.

Rutherfordton.—Quartz, pseudomorphous after calcite (!).

Shemwell mine.—Arborescent gold (!).

Second Broad River.—Head of it, gold in veins and placers; pyrite.

Twitty's mine.—Diamond (!).

At the gold placers generally.—Gold; corundum in grains and crystals; menaccanite; rutile; chromite; brookite; rock crystal; garnet; zircon (!); epidote; samarskite; fergusonite; xenotime (!); monazite; wolframite (?).

Elsewhere.—Amethyst; melanterite; alunogen; fergusonite; anatase; corundum; fibrolite; tourmaline; gold; pyrite; meteoric iron.

SAMPSON.

Calcite in marl beds; lignite.

STANLEY.

Hearne mine.—Gold; pyrite; chalcopyrite; calcite; chlorite; serpentine.

Crowell mine.—Gold.

Elsewhere.—Gold in veins and placers.

STOKES.

Bolejack's quarry.—Calcite (!); phlogopite; actinolite.

Coffee Gap.—Lazulite (!) with muscovite in quartz.

Danbury.—Magnetite (!); pyrolusite; cyanite; actinolite; at Roger's ore bank, titanite; sulphur (!) in a limonite quartz geode; asbestus; hornblende; pyrite in muscovite; 7 miles east of Danbury, hornblende.

Dan River.—Opalescent quartz; anthracite and bituminous coal; prochlorite; hematite; magnetite.

Germanton.—Fossil wood (!); 2 miles east, serpentine; calcite; garnet.

Moore's Mill.—Manganese garnet.

Peter's Creek.—Sulphur (!).

Sauratown Mountain.—Itacolumite (!); asbestus.

Snow Creek.—Hematite, at Martin's quarry; chalcedony; hornstone; phlogopite; granular calcite; agate; amethyst; hyalite; jasper; hematite; albite; 6 miles east, pyrolusite.

Stokesburg.—Rock crystal; anthracite and bituminous coal.

Elsewhere.—Copper; graphite; chalcopyrite; muscovite in pyrite; gold in pyrite; siderite; tourmaline; talc; muscovite (large plates); epidote; limonite; calcite, granular, on Little Yadkin and Dan Rivers.

SURRY.

Dobson.—Ten miles north, manganese garnet; pyrolusite; talc in green crystals; serpentine: steatite; actinolite; breunnerite; magnesite; magnetite; chlorite; hausmannite (?); wad; near Dobson, magnetite in prochlorite.

Ararat River.—Four miles southeast of Mount Airy, pyrite (!); magnetite (!); garnet; white cyanite (!).

Chestnut Mountain.—Octahedral magnetite (!).

Fisher's Peak.—Octahedral magnetite.

Pilot Mountain.—Talc (!).

Tom's Creek.—Magnetite.

Rockford.—Steatite.

War Hill.—Milky quartz.

Williams's mine.—Magnetite.

Elkin.—Barite; galenite; pyrite; chalcopyrite; 2 miles east, chalcopyrite; 10 miles north, limonite; hematite; 5 miles northeast, pyrite; chalcopyrite; chrysocolla.

Elsewhere.—Graphite; tourmaline; garnets; magnetite; limonite; chalcopyrite; sulphur; galenite; pyrrhotite; pyrite; psilomelane; asbestus.

SWAIN.

Bryson City.—Rutile; zoisite; limonite after pyrite.

Oconaluftee River.—Gold; galenite, argentiferous; pyrite; chalcopyrite.

A. Nichols's.—Pyrolusite; chalcocite; tourmaline.

Quallatown.—Gold, in placers.

Elsewhere.—Itacolumite; magnetite; hematite; limonite; talc.

TRANSYLVANIA.

Boyston River.—Gold, in placers; granular calcite; limonite.

Davidson River.—Chalcopyrite; pyrite; flinty quartz.

Mills's River.—Calcite.

Brevard.—Chlorite; graphite; limonite after pyrite; kaolin.

Elsewhere.—Pyrite; chalcopyrite; rose quartz; pyrrhotite; tourmaline; graphite; near mouth of Looking-glass Creek, kaolin.

TYRRELL—(None.)

UNION.

Lemmond mine.—Gold (!); electrum (!); galenite; sphalerite; pyrite; arsenopyrite; pyromorphite.

Long mine.—Gold; galenite.

Moore's mine.—Gold; sphalerite; pyrite; chalcopyrite; galenite.

Pewter mine.—Electrum.

Phifer mine.—Gold; silver; galenite; also at Lewis mine and Washton mine.

Stewart mine.—Gold (!); electrum (!); galenite; sphalerite; pyrite; arsenopyrite; pyromorphite.

Union mine.—Gold; also at Davis mine, Dulin mine, Fox Hill mine, Crump mine, Cureton mine.

Walkup's mine.—Barite (!), granular.

Smart mine.—Gold; pyrite; chalcopyrite; galenite; sphalerite.

Elsewhere.—Gold, in veins and placers.

VANCE.

Near Henderson.—Pyrite; chalcopyrite; talc; calcite.

Kittrell's.—Chalcedony.

WAKE.

Forestville.—Seven miles west, magnetite; menaccanite; prochlorite.

Barton Creek.—Pyrite, large cubes; hematite, pseudomorphous after pyrite; tourmaline; chlorite.

Brassfields.—Calcite; chalcedony.

Witherspoon's.—Granular calcite.

Wyatt's.—Limonite.

Cary.—Pyrite; hematite; martite; sulphur.

Northwest corner of county.—Serpentine; asbestus; actinolite; steatite; cyanite.

Soapstone Church.—Talc; asbestus; serpentine.

Morrisville.—Granular calcite.

Raleigh.—Menaccanite (!); epidote; hematite; magnetite; chrysolite (?); malachite in granite; muscovite; paragonite (?); near Raleigh, pyrite; chalcopyrite; graphite; smoky quartz; garnet; biotite; 3 miles west, orthoclase; 4 miles northwest, amethyst; 4½ miles west, pyrite; chalcopyrite; psilomelane; 8 miles west, pyrite and limonite after pyrite.

Elsewhere.—Graphite (!), at Tucker's Mill; pyrite; magnetite; amethyst; tourmaline; calcite; at mill on Cliffton's Branch, vermicular quartz; in Little River Township, halloysite.

WARREN.

Middleburg.—Micaceous hematite; quartz crystals.

Warrenton.—Eight miles south, limonite after pyrite; 9 miles south, asbestus.

Ransom's Bridge.—Gold; garnet.

Elsewhere.—Quartz crystals; magnetite; epidote; gold, in placers; garnets.

WASHINGTON.

Calcite, in marl beds.

WATAUGA.

Beech Mountain.—Fine-grained galenite (!); pyrite; magnetite; hematite; at Pogie, galenite.

Cooke's Gap.—Arsenopyrite; hematite (!); magnetite (!); itacolumite (!); limonite; martite.

Cove Creek.—Magnetite; limonite.

Rich Mountain.—Head of Cove Creek; chromite; quartz crystals; actinolite; chrysolite; epidote; penninite; tremolite.

Beaver Dam Creek.—Magnetite.

Elk Knob.—Pyrite; chalcopyrite; pyrrhotite; epidote; limonite; garnet.

Flannery mine.—Argentiferous galenite.

Miller mine.—Pyrite; chalcopyrite; limonite; epidote; chrysolite.

Watauga River.—Calcite; epidote; chlorite.

Elk River.—Jasper; epidote; chlorite; calcite; at L. Banner's, prochlorite; pyrite; quartz.

Hardin mine.—Gold, in placers.

Boone Fork.—Quartz crystals (fine).

Near Boone.—Actinolite; cyanite.

Elsewhere.—Gold in placers; galenite; fluorite; epidote; limonite; magnetite; cyanite; talc; chromite; chlorite; menaccanite; asbestus.

WAYNE.

Fossil wood; lignite; pyrite; calcite, in marl beds.

WILKES.

Wilkesboro.—Two miles north, serpentine; talc; garnet.

Mulberry River.—Magnetite.

Blue Ridge.—Three miles south, on road to Jefferson, garnet; orthoclase; apatite.

Bending Rock Mountain.—Itacolumite.

Brushy Mountains.—Asbestus.

Roaring River.—Magnetite.

Elk Creek.—Galenite; cerussite.

Flint Knob.—Galenite (argentiferous); pyrite.

Elkin Creek.—Barite; limonite; galenite; cerussite.

Honey Creek.—Rutile (!) in acicular crystals in brownish amethyst

Stony Hill.—Chalcopyrite; muscovite.

Trap Hill mine.—Galenite; pyrrhotite; chalcopyrite (auriferous); pyrite; rutile; garnet; tourmaline; magnetite.

Reddie's River.—Serpentine.

Elsewhere.—Graphite; corundum (!), mostly altered into cyanite; pyrite; cyanite (!); mixture of muscovite, margarite, etc., resulting from the alteration of cyanite.

WILSON.

Contentnea Creek.—Orthoclase; biotite.
Stantonsburg.—Pyrite.
Turkey Creek.—Amethystine quartz.
Elsewhere.—Calcite in marl beds; limonite.

YADKIN.

Near Yadkinville.—Gold.
Boyden's quarry.—Calcite, compact and granular.
Campbell mine.—Magnetite.
Hobson's mine.—Magnetite; tremolite; magnetite (!) at East Bend and elsewhere.
Near Forks of Yadkin River.—Calcite.
Jonesville.—Pyrite in cubes in slate; chalcopyrite.

YANCEY.

Grassy Knob (Black Mountains).—Cyanite; muscovite.
Black Mountain.—Graphite.
Bald Mountain.—Grayish green actinolite; magnetite.
Burnsville.—Platinum (?); labradorite (!) 6 miles north of Burnsville; tourmaline at Parrot's Ford, 3 miles from Burnsville; tantalite (!); 4 miles north of Burnsville, chromite and talc; 1 mile west, kaolin; 3½ miles west, margarite.
Hampton's, Mining Creek.—Chromite (!); chalcedony; enstatite; tremolite (!); actinolite; asbestus; chrysolite (!); orthoclase; talc (!); serpentine; deweylite; penninite; magnesite; epidote, in fine green crystals; bronzite; hornblende; prochlorite (?).
Hurricane Mountain.—Cyanite (!); titanite; muscovite.
Bald Creek.—Chrysolite; talc; asbestus; serpentine; tremolite; chlorite; pyrite; actinolite; epidote.
Ivy River.—Menaccanite.
Ray's mica mine.—Fluorite (!); pseudomorphous after apatite; yttrocerite (?); beryl (!); garnet; zircon; rutile; muscovite (!), also a scaly pink-variety; orthoclase; tourmaline (!), black and yellowish green; kaolinite; columbite; apatite; monazite, very rare; autunite; amazon stone; cyanite; albite; smoky quartz; quartz crystals; actinolite; talc; glassy feldspar.
Mitchell's Peak.—Cyanite; fibrolite; garnet; biotite; tourmaline.
South Toe River.—Uranochre (?); muscovite; garnet; hyalite; gummite; autunite; garnet.
Proffit's.—Corundum; muscovite; asbestus; garnet; penninite (?); talc; near Proffit's, chrysotile; fibrous talc.
Young's mine.—Enstatite; chlorite; serpentine; chrysolite; chromite; talc; asbestus; tremolite; pyrite; manganese garnet, and garnet crystals; bronzite; tourmaline; muscovite.

Westall mine.—Cyanite.

Presnell (Young's) mine.—Muscovite; albite; apatite; autunite.

Gibb's mine.—Muscovite; albite; garnet; glassy feldspar.

Guggenheim's mine.—Muscovite; albite; manganese garnet; apatite; hyalite; tourmaline; autunite.

Rocky Creek.—Muscovite; pyrite; graphite.

Elsewhere.—Graphite; allanite; cyanite; columbite; magnetite; on Crabtree Creek, massive reddish garnet; rutile; muscovite; in many mica mines, pyrite.

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7. Mapoteca Geologica Americana. A Catalogue of Geological Maps of America (North and South), 1752–1881, in geographic and chronologic order, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist. T. M. Chatard, assistant chemist. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call. Introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 24 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, with a Historical Sketch of the Territorial Changes, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the Higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, with Notes on the Geology of the District, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation. A Report on the Region between the Grand and Moreau Rivers, Dakota, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary Fossils and recent forms from American Localities between Cape Hatteras and Cape Roque, including the Bermudas, by William Healey Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Maryland, by George Huntington Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles Doolittle Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnida, by Samuel Hubbard Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a Preliminary Study, by Albert C. Peale 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by J. S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus. 1886. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by J. S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis. 1887. 8°. 10 pp. 4 pl. Price 5 cents.

41. On the Fossil Faunas of the Upper Devonian—the Genesee Section, New York, by Henry S. Williams. 1887. 8°. 121 pp. 4 pl. Price 15 cents.

42. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist. 1887. 8°. 152 pp. 1 pl. Price 15 cents.

43. Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson. 1887. 8°. 189 pp. 21 pl. Price 15 cents.

44. Bibliography of North American Geology for 1886, by Nelson H. Darton. 1887. 8°. 85 pp. Price 5 cents.

45. The Present Condition of Knowledge of the Geology of Texas, by Robert T. Hill. 1887. 8°. 94 pp. Price 10 cents.

46. Nature and Origin of Deposits of Phosphate of Lime, by R. A. F. Penrose, jr., with an Introduction by N. S. Shaler. 1888. 8°. 143 pp. Price 15 cents.

47. Analyses of Waters of the Yellowstone National Park, with an Account of the Methods of Analysis employed, by Frank Austin Gooch and James Edward Whitfield. 1888. 8°. 84 pp. Price 10 cents.

48. On the Form and Position of the Sea Level, by Robert Simpson Woodward. 1888. 8°. 88 pp. Price 10 cents.

49. Latitudes and Longitudes of Certain Points in Missouri, Kansas, and New Mexico, by Robert Simpson Woodward. 1889. 8°. 133 pp. Price 15 cents.

50. Formulas and Tables to facilitate the Construction and Use of Maps, by Robert Simpson Woodward. 1889. 8°. 124 pp. Price 15 cents.

51. On Invertebrate Fossils from the Pacific Coast, by Charles Abiathar White. 1889. 8°. 102 pp. 14 pl. Price 15 cents.

52. Subaërial Decay of Rocks and Origin of the Red Color of Certain Formations, by Israel Cook Russell. 1889. 8°. 65 pp. 5 pl. Price 10 cents.

53. The Geology of Nantucket, by Nathaniel Southgate Shaler. 1889. 8°. 55 pp. 10 pl. Price 10 cents.

54. On the Thermo-Electric Measurement of High Temperatures, by Carl Barus. 1889. 8°. 313 pp. incl. 1 pl. 11 pl. Price 25 cents.

55. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1886–'87. Frank Wigglesworth Clarke, chief chemist. 1889. 8°. 96 pp. Price 10 cents.

56. Fossil Wood and Lignite of the Potomac Formation, by Frank Hall Knowlton. 1889. 8°. 72 pp. 7 pl. Price 10 cents.

57. A Geological Reconnaissance in Southwestern Kansas, by Robert Hay. 1890. 8°. 49 pp. 2 pl. Price 5 cents.

58. The Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, by George Frederick Wright, with an introduction by Thomas Chrowder Chamberlin. 1890. 8°. 112 pp. incl. 1 pl. 8 pl. Price 15 cents.

59. The Gabbros and Associated Rocks in Delaware, by Frederick D. Chester. 1890. 8°. 45 pp. 1 pl. Price 10 cents.

60. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1887–'88. F. W. Clarke, chief chemist. 1890. 8°. 174 pp. Price 15 cents.

61. Contributions to the Mineralogy of the Pacific Coast, by William Harlow Melville and Waldemar Lindgren. 1890. 8°. 40 pp. 3 pl. Price 5 cents.

62. The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan; a contribution to the subject of dynamic metamorphism in eruptive rocks, by George Huntington Williams; with an introduction by Roland Duer Irving. 1890. 8°. 241 pp. 16 pl. Price 30 cents.

63. A Bibliography of Paleozoic Crustacea from 1698 to 1889, including a list of North American species and a systematic arrangement of genera, by Anthony W. Vogdes. 1890. 8°. 177 pp. Price 15 cents.

64. A Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1888–'89. F. W. Clarke, chief chemist. 1890. 8°. 60 pp. Price 10 cents.

65. Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio, and West Virginia, by Israel C. White. 1891. 8°.

66. On a Group of Volcanic Rocks from the Tewan Mountains, New Mexico, and on the occurrence of Primary Quartz in certain Basalts, by Joseph Paxson Iddings. 1890. 8°. 34 pp. Price 5 cents.

67. The relations of the Traps of the Newark System in the New Jersey Region, by Nelson Horatio Darton. 1890. 8°. 82 pp. Price 10 cents.

68. Earthquakes in California in 1869, by James Edward Keeler. 1890. 8°. 25 pp. Price 5 cents.

69. A Classed and Annotated Bibliography of Fossil Insects, by Samuel Hubbard Scudder. 1890. 8°. 101 pp. Price 15 cents.

70. Report on Astronomical Work of 1889 and 1890, by Robert Simpson Woodward. 1890. 8°. 79 pp. Price 10 cents.

71. Index to the Known Fossil Insects of the World, including Myriapods and Arachnida, by Samuel Hubbard Scudder. 1891. 8°. 744 pp. Price 50 cents.

72. Altitudes between Lake Superior and the Rocky Mountains, by Warren Upham. 1891. 8°. 229 pp. Price 20 cents.

73. The Viscosity of Solids, by Carl Barus. 1891. 8°. xii, 139 pp. 6 pl. Price 15 cents.

74. The Minerals of North Carolina, by Frederick Augustus Genth. 1891. 8°. 119 pp. Price 15 cents.

75. Record of North American Geology for 1887 to 1889, inclusive, by Nelson Horatio Darton. 1891. 8°. 173 pp. Price 15 cents.

77. The Texan Permian and its Mesozoic types of Fossils, by Charles A. White. 1891. 8°. 51 pp. 4 pl. Price 10 cents.

In press:

76. A Dictionary of Altitudes in the United States (second edition), compiled by Henry Gannett.

78. A report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1889–'90. F. W. Clarke, chief chemist.

79. *A Late* Volcanic Eruption in Northern California and its peculiar lava, by J. S. Diller.

80. Correlation papers—Devonian and Carboniferous, by Henry Shaler Williams.
81. Correlation papers—Cambrian, by Charles Doolittle Walcott.
82. Correlation papers—Cretaceous, by Charles A. White.

In preparation:

— The Compressibility of Liquids, by Carl Barus.
— The Eruptive and Sedimentary Rocks on Pigeon Point, Minnesota, and their contact phenomena, by W. S. Bayley.
— A Bibliography of Paleobotany, by David White.

STATISTICAL PAPERS.

Mineral Resources of the United States, 1882, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°. viii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1887, by David T. Day. 1888. 8°. vii, 832 pp. Price 50 cents.

Mineral Resources of the United States, 1888, by David T. Day. 1890. 8°. vii, 652 pp. Price 50 cents.

In preparation:

Mineral Resources of the United States, 1889 and 1890.

The money received from the sale of these publications is deposited in the Treasury, and the Secretary of the Treasury declines to receive bank checks, drafts, or postage stamps; all remittances, therefore, must be by POSTAL NOTE or MONEY ORDER, made payable to the Librarian of the U. S. Geological Survey, or in CURRENCY, for the exact amount. Correspondence relating to the publications of the Survey should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *July*, 1891

DEPARTMENT OF THE INTERIOR

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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

RECORD

OF

NORTH AMERICAN GEOLOGY FOR 1887 TO 1889 INCLUSIVE

BY

NELSON HORATIO DARTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
POTOMAC DIVISION OF GEOLOGY,
Washington, D. C., June 1, 1890.

SIR: I have the honor to forward herewith a Record of North American Geology for the years 1887 to 1889, inclusive, which is submitted for publication as a bulletin of the Survey.

Very respectfully, your obedient servant,

N. H. DARTON,
Assistant Geologist.

Hon. J. W. POWELL,
Director.

RECORD OF NORTH AMERICAN GEOLOGY FOR 1887 TO 1889.

By Nelson Horatio Darton.

INTRODUCTORY.

The literary scope of this record includes geologic publications printed in North America and publications on North American geology wherever printed. Chronologically it includes publications issued during the years 1887, 1888, and 1889. The List of Publications Examined, page 9, indicates the range of the sources of information.

The entries are comprised in the three following classes, all being arranged in a single alphabetic sequence:

I. *Principal entries.*—Consisting of full titles of separate contributions classified by authors, with subarrangement by dates, together with as much of the usual bibliographic information as appears necessary in a work of this kind. The descriptive note relates only to the geologic contents of the contribution. The size of volume is given only when other than octavo. The extent of papers less than a page in length is indicated thus: $\frac{1}{8}$ p., $\frac{1}{4}$ col., 3 lines.

II. *Titles of containing publications.*—Entered as headings, under which authors' names and short titles of the contained papers are listed in their order of precedence.

III. *Subject references.*—Geographic, stratigraphic, and miscellaneous geologic headings under which abbreviated titles of papers are classified for cross reference to principal entries. A key to these subject references is given on page 8.

KEY TO THE SUBJECT REFERENCES.

Geographic:

Alabama.
Alaska, and the other States and Territories.
Asia.
Bermudas.
Canada, comprising all British possessions in North America.
Central America.
Europe.
Hawaiian Islands.
Mexico.
New Zealand.
South America.

Stratigraphic:

Pleistocene.
Tertiary.
Cretaceous, including Laramie and Potomac.
Jurassic-Triassic.
Carboniferous, including Permian.
Devonian.
Silurian, Upper.
Silurian, Lower.
Cambrian.
Archean, comprising all pre-Cambrian formations.

Miscellaneous:

Geologic history.
Geologic philosophy.
Petrography.

LIST OF PUBLICATIONS EXAMINED.

American Academy of Arts and Sciences, Proceedings, vol. 22; vol. 23, part 1.
American Anthropologist, vols. 1, 2. Washington.
American Association for the Advancement of Science, Proceedings, vols. 36, 37. Salem, Mass.
American Geographical Society, Bulletin, vols. 19–21. New York.
American Geologist, vols. 1–4. Minneapolis, Minn.
American Institute of Mining Engineers, Transactions, vol. 15, p. 536 to end; vols. 16, 17. New York.
American Journal of Science, vols. 33–38. New Haven, Conn.
American Museum of Natural History, Bulletin, vol. 2, Nos. 1–2. New York.
American Naturalist, vols. 21, 22; vol. 23, January to September. Philadelphia.
American Philosophical Society, Proceedings, vols. 24, 25, Nos. 124–130. Philadelphia.
——— Transactions, vol. 16, new series, part 2. Philadelphia.
Appalachia, vol. 4, No. 4; vol. 5. Boston.
Arkansas Geological Survey, Report for 1888, vols. 1–3. Little Rock.
Boston Society of Natural History, Memoirs, vol. 4, Nos. 1–6. Boston.
Boston Society of Natural History, Proceedings, vol. 23, p. 257, to vol. 24, p. 288. Boston.
British Association for the Advancement of Science, Report of fifty-sixth, fifty-seventh, and fifty-eighth meetings. London.
California Academy of Sciences, Bulletin, vol. 2, Nos. 6–8. San Francisco.
California Academy of Sciences, Proceedings, 2d series, vol. 1, parts 1, 2.
California State Mining Bureau. Seventh and Eighth Annual Reports of the State Mineralogist, William Irelan, jr. Sacramento.
Canada, Geological and Natural History Survey, Annual Report, vol. 2, 1886–'88. Montreal.
Canada, Royal Society, Transactions, vols. 4–6. Montreal.
Canadian Institute, Proceedings, vol. 4, No. 2, to vol. 6, No. 2. Toronto.
Canadian Record of Science, vol. 2, No. 5, to vol. 3, No. 6. Montreal.
Cincinnati Society of Natural History, Journal, vol. 10 to vol. 12, No. 3. Cincinnati, Ohio.
Colorado State School of Mines, Field work and Analyses. Golden, Colorado, 1886.
——— Biennial Report, 1886; Annual Report, 1887.
Colorado Scientific Society, Proceedings, vol. 2, parts 2, 3; vol. 3, part 1. Denver.
Connecticut Academy of Arts and Sciences, Transactions, vol. 7, part 2. New Haven.
Cornwall, Royal Geological Society, Transactions, vol. 11, parts 2, 3. Penzance.
Dakota School of Mines, Preliminary Report upon the Geology and Mineral Resources of the Black Hills of Dakota. Rapid City.
Davenport Academy of Sciences, Proceedings, vol. 4; vol. 5, part, 1. Davenport, Iowa.
Dennison University, Scientific Laboratories, Bulletin, vol. 2; vol. 3, part 1; vol. 4, parts 1, 2. Granville, Ohio.
Deutschen geologischen Gesellschaft, Zeitschrift, vol. 39; vol. 40, parts 1–3. Berlin.

Edinburgh Geological Society, Transactions, vol. 5, parts 2–4. Edinburgh.
Elisha Mitchell Scientific Society, Journal, 1887–'89. Raleigh, North Carolina.
Engineering and Mining Journal, vols. 43–48. New York.
Essex Institute, Bulletin, vols. 19, 20; vol. 21, Nos. 1–6. Salem, Massachusetts.
Forum, 1888. New York.
Franklin Institute, Journal, vols. 123–127. Philadelphia.
Geologists' Association, Proceedings, vol. 10; vol. 11, Nos. 1–5. London.
Geological Society, Quarterly Journal, vols. 43–45. London.
Geological Magazine, Third decade, vols. 4–6. London.
Geological and Scientific Bulletin, vol. 1, Nos. 2–7 and 9–12. Austin, Texas.
Glasgow Geological Society, Transactions, vol. 8, parts 1, 2.
Harvard College, Museum of Comparative Zoölogy, Bulletin, vol. 16, Nos. 1–4, vol. 17, Nos. 1, 2, 5, 6, vol. 18, Cambridge, Massachusetts.
——— Memoirs, vol. 16, Nos. 1–3. Cambridge, Massachusetts.
Hamilton Association, Journal, vols. 2, 3.
International Congress of Geologists, American Committee, Reports, 1888.
Iowa Historical Record, vols. 3, 4. Des Moines, Iowa.
Iowa State University, Laboratories of Natural History, Bulletin, vol. 1, No. 1. Iowa City.
Ireland, Royal Geological Society, Journal, vol. 17, part 2; vol. 18, part 2. Dublin.
Johns Hopkins University, Circulars, Nos. 53–57. Baltimore.
Kansas Academy of Science, Transactions, 1885–'86, vols. 10, 11. Topeka.
Kansas Board of Agriculture, 5th Report Topeka.
Kentucky Geological Survey, Reports on Jackson purchase, Kentucky River, Round Gap region, and Letcher, Harlan, Leslie, Perry, Breathitt, Spencer, Nelson, Garrard, Henry, Shelby, Oldham, Mason, Marion, Bath, and Fleming counties, and Rocks of central Kentucky.
Lackawanna Institute of History and Science, Proceedings, vol. 1. Scranton, Pennsylvania.
Liverpool Geological Association, Transactions, vols. 7, 8. Liverpool.
Liverpool Geological Society, Proceedings, vol. 5, parts 3, 4. Liverpool.
Louisville and Nashville Railroad. Mineral resources of upper Cumberland Valley, by A. S. McCreath and E. V. d'Invilliers. Louisville.
Manchester Geological Society, Transactions, vol. 19; vol. 20, parts 1–8. Manchester.
Maryland Academy of Sciences, Transactions, 1888, pp. 1–68. Baltimore.
Massachusetts, Gazetteer of Hampshire County, 1854–'87, by W. B. Gay. Syracuse, New York.
Meriden Scientific Association, Transactions, vols. 2, 3. Meriden, Connecticut.
Minnesota Geological and Natural History Survey, Geology of Minnesota, Final report, vol. 2, by N. H. Winchell and Warren Upham.
Minnesota Geological and Natural History Survey, Sixteenth and Seventeenth Annual Reports. St. Paul.
——— Bulletin, No. 5.
Minnesota Academy of Natural Sciences, Bulletin, vol. 3, No. 1. Minneapolis.
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National Geographic Magazine, vol. 1. Washington.
Nature, 1887–'89.
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New Jersey Geological Survey, Reports of State Geologist for 1886, 1887, and 1888. Trenton.
New Orleans Academy of Sciences, Papers, vol. 1, No. 2.
New York Academy of Sciences, Annals, vol. 4, Nos. 1–11. New York.
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——— Fortieth Annual Report, for year 1886. Albany.
Nova Scotian Institute of Natural Science, Proceedings and Transactions, vol. 7, parts 1–3. Halifax.
Ohio Geological Survey, Report, vol. 6, Economic Geology. Columbus.
Ottawa Naturalist, vols. 1, 2; vol. 3, Nos. 1–3. Ottawa.
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——— Atlases, HH–HHH, and AA, parts 2–5.
Peoria Scientific Association, Bulletin, vol. 1. Peoria, Illinois.
Philadelphia Academy of Natural Sciences, Journal, 2d series, vol. 9, part 2. Philadelphia.
——— Proceedings 1887–'88; 1889, parts 1, 2. Philadelphia.
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U. S. Geological Survey, Bulletins Nos. 34–54. Washington.
——— Mineral Resources, 1887.
——— Monographs vols. XIII and XIV.
——— Seventh Report, 1885–'86. Washington.
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Vienna, K.-k. geologische Reichsanstalt, Verhandlungen, 1888, Nos. 1–7. Vienna.
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ABBOTT, Charles C. On the antiquity of man in the valley of the Delaware.

Boston Soc Nat. Hist., Proc., vol. 23, pp. 424–426. 1888.

Includes references to the genesis and relation of the Trenton gravels.

ADAMS, Frank D. On the coal-bearing rocks of Canada.

British Assoc. Adv. Sci., Report of 56th Meeting, 1886, pp. 639–641. 1887.

General description of the Carboniferous coal measures of Nova Scotia and New Brunswick, the lignites and anthracites of the Northwest Territory, and the bituminous coal of Vancouver's Island.

—— The anorthosite rocks of Canada.

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Describes the mineralogic constituents and variations of the Upper Laurentian or Norian series occurring in detached areas in the great Laurentian region.

—— [Analyses—Shell marl from Anticosti and Carbonaceous schist from Lake of the Woods.]

Canada Geol. and Nat. Hist. Survey, Report, 1886, part I, p. 41, ½ p. 1887.

—— On the microscopical character of the ore of the Treadwell mine, Alaska.

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Includes petrographic description of associated rock.

—— and **LAWSON**, Andrew C. On some Canadian rocks containing scapolite, with a few notes on some rocks associated with the apatite deposits.

Canadian Record Science, vol. 3, pp. 185–201, 1888.

Abstract, Am. Naturalist, vol. 23, pp. 169–170, p. (February No.), 1890.

Petrographic description of apatite-bearing pyroxenites from Portland West, the McLaurian mine, Star Hill mine, and Blessington mine, amphibolites from Arnprior, and scapolite-bearing rocks from near Arnprior, in Frontenac and Addington counties, and the Perry Sound region. Discussion of associations and history of some of the contained minerals.

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AGASSIZ, Alexander. The coral reefs of the Hawaiian Islands.

Harvard College, Mus. Comp. Zool., Bull., vol. 17, pp. 121–170, pls. I–XII. 1889.

Review of theories of the origin of coral reefs, and an account of recent observations on the relations of the coral formations of the Hawaiian Islands.

Alabama, absence of separable Oligocene, ALDRICH.
analyses of iron ores, FLEMING.
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relations of Grand Gulf series, HILGARD.
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Alaska, glaciation, DAWSON, G. M.
Muir Glacier, CHICKERING. WRIGHT.
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Treadwell mine ores, ADAMS. DAWSON, G. M.

ALDRICH, T. H. [On the absence of separable Oligocene in the Gulf Tertiary region.]

International Congress of Geologists, Am. Committee, Reports, 1888. F., p. 7, 8 lines. Am. Geologist, vol. 2, p. 273. 1888.
Statement of opinion.

ALLEN, Joseph H. Western Kentucky Coals and cokes.

Am. Inst. Mining Engineers, Trans., vol. 16, pp. 581–593. 1888.
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American Anthropologist, vol. 2.

Geologic antecedents of man in the Potomac Valley, McGEE.

American Association for the Advancement of Science, Proceedings, vol. 36.

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—— The Huronian system of Canada.

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Abstract of paper read to Royal Society of Canada. 1888.

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—— Report on an exploration of portions of the At-ta-wa-pish-kat and Albany Rivers, Lonely Lake to James' Bay.

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—— Notes on the iron ores, fuel, and improved blast-furnace practice of the Birmingham district.

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—— The Geology of Fernando de Noronha, part I.

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—— On an Archean plant from the white crystalline limestone of Sussex County, New Jersey.

New York Acad. Sci., Annals, vol. 4, pp. 123–124; pl. VII. 1888.

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Notice of new localities.

—— [Notice of a new exposure of Cretaceous near Grassmere Station, Staten Island.]

Staten Island Nat. Sci. Assoc., Proc., March, 1889.

Am. Naturalist, vol. 23, p. 563; ½ p. 1889.

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—— [Remarks on the yellow gravel formation.]

Staten Island Nat. Sci. Assoc., Proc., April, 1889, 1 page.

Am. Naturalist, vol. 33, pp. 1032–1033. 1889.

Discussion of its origin.

—— [Remarks on the relations of the crystalline rock series in the New York-New Jersey region.]

New York Acad. Sci., Trans., vol. 8, pp. 52–53. 1889.

Age and equivalency, especially in the Westchester County and Peekskill region.

—— [Remarks on recent discoveries in local Cretaceous and Quaternary geology.

New York Acad. Sci., Trans., vol. 8, p. 177. 1889.

Description of the occurrence of fossil-bearing concretions in the plastic clay series on Staten Island and on the Raritan River, New Jersey; an outcrop of kaolin and of Cretaceous gravels containing Paleozoic fossils at Prince's Bay, and an exposure of bowlder clay at Arrochar, Staten Island; discusses the origin and history of the fossiliferous pebbles in the Cretaceous and the yellow gravel deposits, and the relations and age of the ferruginous quarts and "jasperoid rock" overlying the serpentines of Hoboken and Staten Island.

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Am. Geologist, vol. 3, pp. 214–215. 1889.

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—— The terminal moraine near Louisville.

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Colorado School of Mines, Report of field work and analyses, 1886, pp. 5–16. 1888.

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—— Three coals from Gulf, North Carolina.

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Am. Jour. Sci., 3d series, vol. 35, pp. 483–488. 1888.

Includes an analysis of the associated peridotite and a report on its mineralogic constitutents by J. S. Diller. Also a reference to the peridotite of Webster, North Carolina, by J. S. Diller.

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New York, Sixth Report of the Geologist, 1886, pp. 34–35. 1887.

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CLAYPOLE, E. W. The lake age in Ohio, or some episodes in the retreat of the North American glacier.

Edinburgh Geol. Soc., Trans., vol 5, pp. 421–458, 4 plates. 1887.

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—— The materials of the Appalachians.

Am. Naturalist, vol. 21, pp. 955–962, 1054–1060. 1887.

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CLAYPOLE, E. W.—Continued.

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Am. Assoc. Adv. Science, Proc., vol. 36, p. 218. 1888.

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—— The four great sandstones of Pennsylvania. [Abstract.]

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—— Singular subterranean commotion near Akron, Ohio.

Am. Geologist, vol. 1, pp. 190–192. 1888.

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—— On some investigations regarding the condition of the interior of the earth.

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—— The eccentricity theory of glacial cold versus the facts.

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Includes discussion of the rate of recession of Niagara Falls, the falls of St. Anthony, and various minor falls in New York and Ohio, as bearing on the date of the last period of glacial cold. Also discusses the history of the Niagara-St. Lawrence drainage and the Upper Mississippi.

—— Glaciers and glacial radiants in the ice age.

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—— The story of the Mississippi-Missouri.

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A general sketch of the geologic history of North America with especial reference to the Mississippi–Missouri region.

—— Falls of rock at Niagara.

Nature, vol. 39, p. 367, ½ col. 1889.

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CLAYTON, Joshua E. The Drumlummon group of veins and their mode of formation.

CLAYTON, Joshua E.—Continued.

Eng. and Mining Jour., vol. 46, pp. 85–88, 106–108, 4°. 1888.

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Description of geologic relations at contact of granite and metamorphic beds. Discussion of the origin and history of the mineralization.

—— The Cœur d'Alene silver-lead mines.

Eng. and Mining Jour., vol. 45, pp. 106–109, 4°. 1888.

Description of geology of region and discussion of structural relations.

[CLERC, F. L.] The lead and zinc ores of southwest Missouri.

Eng. and Mining Jour., vol. 43, pp. 397–398. 1887.

(From a pamphlet not seen.)

Discusses age and origin of slate beds in depressions in surface of Carboniferous limestones and the erosion of the region.

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Review by F. H. Newell, Geol. Magazine, III, vol. 6, pp. 137–139. 1889.

General description of the structure and stratigraphy of the field, including numerous quotations from previous writers. Discussion of the origin and extent of the coal and coke, and relation of the coal measures to adjoining formations, accompanied by maps and sections at Clover Hill, Midlothian, Black Heath, and Deep Run.

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Canada, Royal Soc., Trans., vol. 5, section III, pp. 45–59, pls. 1, 2, 4°. 1888.

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COLLINS, J. H. On the Sudbury copper deposits.

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Includes brief description of geologic relations. Discusses origin of the deposits and their relations to the igneous rocks.

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Cimarron land slide, CROSS.
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mountain upthrusts, Uinta, etc., WHITE, C. A.
northwestern coal region, HEWITT.
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ores of Red Mountain region, SCHWARZ.
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paramorphic origin of certain minerals, CROSS.
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Rocky Mountains a field for original work, HILLS.
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Am. Assoc. Adv. Science, Proc., vol. 36, pp. 213–215. 1888.

Gives stratigraphic sections at several localities. Description of extent and relations and discussion of equivalency of the beds, especially of the sandstone north of Warren.

D.

Dakota School of Mines, Report on Black Hills.

Geology of the Black Hills, CARPENTER.

Mineral resources of the Black Hills, CARPENTER.

Dakota, beaches of glacial Lake Agassiz, UPHAM.

coal, ASHBURNER.

continuance of Lake Cheyenne, TODD.

Cretaceous, UPHAM. WARD. HILL, R. T.

fossil plants and prairies, LEIBERG.

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glacial boundary in southeast Dakota, WRIGHT.

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Tertiary, COPE.

terraces of the Missouri, TODD.

DALL, William H. Notes on the geology of Florida.

Am. Jour. Sci., 3d series, vol. 34, pp. 161–170. 1887.

DALL, William H.—Continued.

Describes the extent of the several superficial and Tertiary formations and discusses their faunal distribution and equivalency, and the synchronism of post-Cretaceous formations in general. Calls attention to many rock outcrops and new fossiliferous localities, and to a series of meridional flexures crossing the Caloosahatchee River.

—— [On the faunal relations of the formations of the Tertiary.]

International Congress of Geologists, Am. Committee Reports, 1888, F., p. 16, ½ p.

Am. Geologist, vol. 2, p. 282. 1888.

Discussion of basis on which Tertiary should be subdivided.

DANA, Edward S. Contributions to the petrography of the Sandwich Islands.

Am. Jour. Sci., 3d series, vol. 37, pp. 441–467, pl. XIV. 1889.

Abstracts, Am. Naturalist, vol. 23, pp. 522–533, ½ p. 1889. Nature, vol. 40, p. 189, 11 lines. 1889.

Petrographic descriptions of lavas. Includes an account of volcanic stalactites and discussion of their origin.

DANA, James D. Volcanic action.

Am. Jour. Sci., 3d series, vol. 33, pp. 102–115. 1887.

Discusses causes and results of volcanic action and a résumé and discussion of the phenomena of Kilauea, Vesuvius, the recent New Zealand eruptions, and other instances.

[—— ?] The origin of mountain ranges considered experimentally, structurally, dynamically, and in relation to their geological history, by T. Mellard Reade [etc.].

Am. Jour. Sci., 3d series, vol. 33, pp. 240–242 1887.

DANA, James D.—Continued.

A brief statement of the theory and a review of its application to continental uplift and the Appalachian trough.

—— On Taconic rocks and stratigraphy, with a geological map of the Taconic region; part 2, the middle and northern part.

Am. Jour. Sci., 3d series, vol. 33, pp. 270–276 392–419, pl. 11. 1887.

[Continued from vol. 29, p. 443, 1885.]

Describes the rocks and a series of sections across the region, and discusses the structural and stratigraphic relations, distribution, and equivalency of the limestones, schists, and quartzites. In a supplement entitled "Two views of Prof. Emmons on the Taconic system," reviews Hunt's "The Taconic question restated," pp. 412–419.

[——?] Report on the geology of New Jersey for 1886.

Am. Jour. Sci., 3d series, vol. 34, p. 71, ½ p. 1887.

Abstract of Britton's report on the Archean and discussion of the use of the term Huronian.

[——] Geology of Long Island.

Am. Jour. Sci., 3d series, vol. 34, pp. 153–155. 1887.

Abstract and review of F. J. H. Merrill's paper described in the bibliography for 1886. Discusses the character of the drift ridges, the identification of the Cretaceous and Tertiary, the uplift of the preglacial formations by the advancing edge of the ice sheet, and the cause of the deep bays in the north shore of the island.

[——?] A pot-hole of remarkable size in Archbald, Pennsylvania.

Am. Jour. Sci., 3d series, vol. 34, p. 489. 1887.

Description, and discussion of its origin.

—— History of the changes in the Mount Loa craters; part I, Kilauea.

Am. Jour. Sci., 3d series, vol. 35, pp. 15–34, pp. 213–228, 282–289, pls. I, IV, V. 1888.

Abstract, Nature, vol. 37, p. 358, 17 lines. 1888.

Includes discussion of the causes and relations of the changes, the mobility of the lavas, the eruptive and crater characteristics of a basalt volcano, size of the Kilauea conduit, and the conditions involved in the various phenomena occurring between the eruptions.

[——] Gradual variation in intensity of metamorphism.

Am. Jour. Sci., 3d series, vol. 35, pp. 82–83, ½ p. 1888.

Refers to illustrative localities west of New Haven, and discusses the occurrence and origin of included masses of granite in that region.

DANA, James D.—Continued.

[——] Fossils of Littleton, New Hampshire.

Am. Jour. Sci., 3d series, vol. 35, p. 255, ½ p. 1888.

Notice of their reference to the Niagara group by Hitchcock in 1884.

—— History of changes in the Mount Loa craters, part III, eruptives of Kilauea and Mount Loa.

Am. Jour. Sci., 3d series, vol. 36, pp. 90–112, 167, 175. 1888.

Discussion of the characteristics and causes of eruption, metamorphism as an effect of volcanic conditions, the origin of the form of Mount Loa, relations of Kilauea to Mount Loa, and the contrast between volcanoes of the Mount Loa and Vesuvius types.

—— History of the changes in the Mount Loa craters, part II, Mokuaweoweo.

Am. Jour. Sci., 3d series, vol. 36, pp. 14–32, pl. 1, 81–90. 1888.

History of eruptions, etc., and discussion of times and time intervals, and the nature and causes of the ordinary activity within the summit crater.

—— Brief history of Taconic ideas.

Am. Jour. Sci., 3d series, vol. 36, pp. 410–427. 1888.

And résumé of present knowledge of the relations in the Taconic region.

—— [On the use of the term "Taconic."]

International Congress of Geologists, Am. Committee Reports, 1888, B, pp. 8–9.

Am. Geologist, vol. 2, pp. 198–199. 1888.

Discussion, of its applicability to lower Paleozoic formations.

—— [On the subdivisions, nomenclature, distinctive features, and origin of some members of the Archean, origin of Serpentine, and the use of terms "Taconic," "Ordovician," and "Cambrian."]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 53–55.

—— Recent observations of Mr. Frank S. Dodge, of the Hawaiian Government Survey, on Halema'uma'u and its débris cone.

Am. Jour. Sci., 3d series, vol. 37, pp. 48–50. 1889.

Evidence of recent elevation of the cone and some other minor changes in the crater.

—— Points in the geological history of the islands Maui and Oahu.

DANA, James D.—Continued.

Am. Jour. Sci., 3d series, vol. 37, pp. 81–103, pls. III, IV. 1889.

Description and discussion of topographic and geologic relations, discussion of geologic history, volcanism and evidence of subsidence. Statement of opinion in regard to Darwin's theory of coral island formation.

—— On the origin of the deep troughs of the Oceanic depression. Are any of volcanic origin?

Am. Jour. Sci., 3d series, vol. 37, pp. 192–202, pl. VII. 1889.

Review of distribution and relations of the deep Oceanic troughs. Accompanied by a bathymetric map.

—— The name Silurian in geology.

Popular Science Monthly, vol. 36, p. 276, ½ p. 1889.

Discussion of nomenclature of the Silurian and Ordovician, and suggestion of term "Ordovician" for the "upper Silurian."

DARTON, Nelson H. Bibliography of North American geology for 1886.

U. S. Geol. Survey, Bull., vol. 7, pp. 343–377, No. 44. 1887.

—— On the great lava flows and intrusive trap-sheets of the Newark system in New Jersey.

Am. Jour. Sci., 3d series, vol. 30, pp. 134–139. 1889.

Discussion of characteristics of extrusive and intrusive masses, and an account of the nature and relations of the traps of the New Jersey region.

—— North American geology for 1886.

Smithsonian Institution, Report, 1886-'87, Part 1, pp. 189–229. 1889.

Classified abstracts of papers.

DARWIN, Charles. The structure and distribution of coral reefs, 3d edition, with an appendix by T. G. Bonney, p. 344. New York. 1889.

Davenport Academy of Natural Sciences, Proceedings, vol. 5, part 1.

A defense of our local geology, BARRIS.

Rockfort shales of Iowa, WEBSTER.

DAVIS, Charles H. S. The Catopterus gracilis.

Meriden Sci. Assoc., Trans., vol. 2, pp. 19–22. 1887.

Remarks on the occurrence of fish remains in the Trias, and a description of the locality at Little Falls, Connecticut.

DAVIS, William Morris. Instruction in geological investigation.

DAVIS, William Morris—Continued.

Am. Naturalist, vol. 21, pp. 810–825. 1887.

In discussing some experiences with his field classes, describes dike contacts in the quarry at Somerville, Massachusetts, and evidences of a former higher level of the sea about Boston.

—— [Results of a study of the mechanical origin of the Triassic monoclinal in the Connecticut valley.]

Boston Soc. Nat. Hist., Proc., vol. 23, pp. 339–341. 1887.

Reviews the various theories and advances a hypothesis to account for the monoclinal attitude. This paper antedates the one on the same subject described in the 1886 bibliography.

[——] The origin of mountain ranges, considered experimentally, structurally, dynamically, and in relation to their geological history. By T. Mellard Reade. London.

Science, vol. 10, p. 139. 1887.

States condition of present opinions on the subject, and briefly relates and reviews the author's theory.

—— The classification of lakes.

Science, vol. 10, pp. 142–143. 1887.

Discusses the formation of lakes in the development of drainage systems, and the effects of lava flows and glacial incursions.

—— The ash bed at Meriden and its structural relations.

Meriden Sci. Assoc., Trans., vol. 3, pp. 23–30. 1888.

Brief notice of the occurrence of the ash-bed; description of contacts of trap with overlying sediments in Lamentation Mountain and of West Rock range, New Haven, and the structural relations in the Meriden region, and sketch of the history of volcanic extrusion, and the mechanism of the uplift and faulting of the Newark formation of the Connecticut valley.

[——] Geographic methods in geologic investigation.

National Geogr. Mag., vol. 1, pp. 11–26. 1888.

Discussion of the status of geographic science and the genetic relations of topographic features. Includes references to structure of the Newark formation of the Connecticut valley, base levels in New Jersey and in eastern Pennsylvania, the relations of topography and drainage to structure and uplift in the Appalachian region and elsewhere, and conditions affecting waterfalls, instanced by some in northeastern Pennsylvania.

DAVIS, William Morris—Continued.

[——] The topographic map of New Jersey.

Science, vol. 12, pp. 206–207. 1888.

Calls attention to topographic features expressing geologic relations or suggesting geologic problems: Submerged mouths of streams along coast, course and termination of ridges in the Newark region, fracture separating Archean highlands from lowlands of softer sediments, and some relations of the preglacial Passaic drainage.

—— The structure of the Triassic formation of the Connecticut valley.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 455–490, pl. 52. 1887.

Abstract, Am. Geologist, vol. 4, pp. 112–113. 1889.

Description and discussion of stratigraphy and the structural relations and characteristics of the igneous members, and a discussion of the mechanical origin of the Triassic monocline, with its faults and flexures.

—— The faults in the Triassic formation near Meriden, Connecticut.

Harvard College, Mus. Comp. Zool. Bull., vol. 16, pp. 61–87, pls. 1–5. 1889.

Detailed description of the relations of traps and sandstones, and structural relations in the Meriden-New Britain region. Illustrated by sketch maps and cross-sections.

—— Topographic development of the Triassic formation of the Connecticut valley.

Am. Jour. Sci., 3d series, vol. 37, pp. 423–434. 1889.

Abstract, Popular Science Monthly, vol. 36, p. 573, ⅓ col. 1890.

Description of structural features in the Meriden region, discussion of the cause and significance of the eastward deflection of the lower Connecticut, and the orographic relations and topographic history of the Connecticut valley region, and comparison of some of its stages with topography of fault systems in the Great Basin and in China.

—— The glacial origin of cliffs.

Am. Geologist, vol. 3, pp. 14–18. 1889.

Discussion of the relations of cliff and talus slopes and their modification by glaciation, instancing those of the Newark regions of New Jersey and the Connecticut valley.

—— Methods and models in geographic teaching.

Am. Naturalist, vol. 23, pp. 566–583. 1889.

Abstract, Johns Hopkins Univ., Circulars, vol. 8, p. 62, ⅓ p, 4°. 1889.

Includes a general discussion of various types and stages of topographic development.

[——] A river pirate.

DAVIS, William Morris—Continued.

Science, vol. 13, pp. 108–109. 1889.

Describes the topographic relations of some drainage features in the southeastern corner of Pennsylvania and discusses their history.

[——] The ice age in North America and its bearing upon the antiquity of man. [By G. F. Wright.]

Science, vol. 14, pp. 118–119. 1889.

A general review of the work.

—— The contoured map of Massachusetts.

Science, vol. 14, pp. 422–423, ⅓ p. 1889.

A general review of the more characteristic topographic features of the State and some suggestions in regard to their geologic history.

—— The rivers and valleys of Pennsylvania.

National Geogr. Mag., vol. 1, pp. 183–253. 1889.

Abstract, Am. Geolgist, vol. 5, pp. 60–61, ⅓ p. 1891.

General description of salient topographic and geologic features, sketch of geologic history, exposition of conceptions of stages of development of drainage systems in general, and discussion of the genesis, history, and relations of the drainage of Pennsylvania.

—— and **WHITTLE**, Charles Livy. The intrusive and extrusive Triassic trap sheets of the Connecticut valley.

Harvard College, Mus. Comp. Zool., Bull., vol. 16, pp. 99–138, pl. 5. 1889.

Abstract, Am. Naturalist, vol. 24, p. 769, 6 lines. 1890.

An account of the general features of intrusive and extrusive sheets in Connecticut and the palisade sheet in New Jersey, and detailed description of the more important localities. Illustrated by maps and sections.

DAWSON, George M. Report on a geological examination of the northern part of Vancouver Island and adjacent coasts.

Canada, Geol. and Nat. Hist. Survey, Report, 1886, part B, pp. 1–107, plates. 1887. Map No. 1 in atlas.

Abstract, Geol. Magazine, III, vol. 6, pp. 130–133. 1889.

Description of Cretaceous, Triassic, volcanics, granites, and drifts, and discussion of their distribution, relations, equivalency, geologic history, the contact relations of the granites and the existence of Carboniferous and Permian. Accompained by a colored geologic map.

—— Notes to accompany a geological map of the northern portion of the Dominion of Canada east of the Rocky Mountains.

DAVIS, William Morris—Continued.

Canada, Geol. and Nat. Hist. Survey, Report, 1886, part R, pp. 62, colored map. 1887.

Abstract, Geol. Magazine, III, vol. 6, pp. 137–138. 1889.

Includes a discussion of the characteristics, equivalency, age, range, structure, distribution, and relations of the various formations and areas, and of the direction of ice movement in the glacial period.

—— On the Canadian Rocky Mountains, with special reference to that part of the Range between the 49th parallel and the headwaters of the Red Deer River.

Canadian Record of Science, vol. 2, pp. 586–300. 1887.

Abstract, without geology, British Assoc. Adv. Sci., Report of the 56th meeting, 1886, pp. 638–639.

General sketch of topographic and geologic features, constituting an abstract of his paper in the Canadian Geol. Survey Report, vol. 1, new series, and described in the 1886 bibliography.

—— On certain borings in Manitoba and the Northwest Territory.

Canada, Royal Soc., Trans., vol. 4, Section IV, pp. 85–99. 1887.

Abstract, Geol. Magazine, 3d decade, vol. 4, pp. 278–289. 1887.

Description of beds passed through at Rosenfield Station, Rat Creek, Solsgirth, Grenfel Station, McLean Station, Regina, Belle Plain Station, Langevin Station, Cassills, and Gleishen Station, and discussion of the equivalency of some of the strata, the thinning of some of the Paleozoic formations toward the region, the relation of the drift deposits, and the stratigraphy of the Cretaceous at the Langevin hole.

—— Note on the Cascade Anthracite basin, Rocky Mountains.

Am. Geologist, vol. 1, pp. 332–333. 1888.

General description of the trough and reference to the horizon and thickness of the Cretaceous in that region.

—— The geological observations of the Yukon expedition, 1887.

Science, vol. 11, pp. 185–186. 1888.

Description of the geology of the Coast Ranges and of the region eastward, to, and including the Rocky Mountains, in west central British Columbia. Includes references to rock series from granites to Miocene, relations of superficial deposits and evidence of glacial action, terraces, striation, and great volcanic ash deposit.

—— Recent observations on the glaciation of British Columbia and adjacent regions.

DAVIS, William Morris—Continued.

Geol. Magazine, 3d decade, vol. 5, pp. 347–350, 1888.

Am. Geologist, vol. 3, pp. 279–253. 1889.

Describes and discusses evidence bearing on the extent and directions of movements of the great ice mass. Includes a brief reference to the occurrence of bowlder clay deposits and to the general terracing of the region.

—— Notes on the ore deposit of the Treadwell mine, Alaska.

Am. Geologist, vol. 4, pp. 84–83. 1889.

Discussion of genesis and geologic relations.

—— On the earlier Cretaceous rocks of the northwestern portion of the Dominion of Canada.

Am. Jour. Sci., 3d series, vol. 38, pp. 120–127. 1889.

Abstract, Nature, vol. 40, p. 404, 11 lines. 1889. Am. Naturalist, vol. 24, p. 769, ½ p. 1890.

Discusses correlation, extent, and geologic history of Kootanie, Queen Charlotte, and other earlier Cretaceous formations in western Canada, relations of overlying conglomeritic series, and Canadian equivalents of the Comanche formation of the Texas region.

—— Glaciation of high points in the southern interior of British Columbia.

Geol. Magazine, decade III, vol. 6, pp. 350–352. 1889.

Abstracts, Ottawa Naturalist, vol. 3, pp. 112–113, ½ p. 1889. Am. Naturalist, vol. 24, p, 771, 4 lines. 1890.

List of some glaciated high summits and remarks on their bearing on the conditions of the glaciation of the region.

—— On the Archean, see **FRAZER**. Report on Archean.

—— See, also, **Dawson**, J. W., and **Dawson**, G. M., on Cretaceous plants from Port McNeill, Vancouver Island.

DAWSON, J. William. On the correlation of the geological structure of the Maritime Provinces of Canada with that of western Europe. (Abstract.)

Canadian Record of Science, vol. 2, pp. 404–406. 1887.

Science, vol. 9, pp. 589–590. 1887.

Discusses the differences between the formations of eastern Canada and those farther west, and points out their close similarity to the formations of western Europe.

—— Notes on fossil woods from the western territories of Canada.

Canadian Record of Science, vol. 2, pp. 499–502. 1887.

Nature, vol. 36, pp. 274–275. 1887.

DAWSON, J. William—Continued.

Discusses the age of the Laramie group and questions of climate and contemporaneity of the lower Eocene flora of different regions.

—— On the relation of the geology of the Arctic and Atlantic basins.

British Assoc. Adv. Science, Report of Fifty-sixth Meeting, 1886, p. 638, ½ p. 1887.

Points out the intimate relations of the Arctic formations to those of eastern North America.

—— Some points in which American geological science is indebted to Canada.

Canada, Royal Soc., Trans., vol. 4, section IV, pp. 1–8. 4°. 1887.

Résumé of the history of geologic research in Canada, especially by Logan. Briefly discusses the subdivisions of the pre-Cambrian of Canada; the relations and equivalency of the "Quebec" group, the position of the "so-called Jurassic of the western territories of the United States," and continental glaciation.

—— On the fossil plants of the Laramie formation of Canada.

Canada, Royal Soc., Trans., vol. 4, section IV, pp. 19–34, pls. 1–2, 4°. 1887.

Describes the extent and stratigraphy of the formation and discusses its equivalency and floral relations.

—— Cretaceous floras of the northwest territories of Canada.

Am. Naturalist, vol. 22, pp. 953–959. 1888.

Abstract of paper read to Royal Society of Canada. 1888.

Discussion of stratigraphic positions, the value of fossil plants in indicating geologic horizons, and the physical conditions and climate indicated by the faunas.

—— Preliminary note on new species of sponges from the Quebec group at Little Metis.

Canadian Record of Science, vol. 3, pp. 49, 59, plate. 1888.

Discussion of the geologic horizon of the beds.

—— Eozoon canadense.

Canadian Record of Science, vol. 3, pp. 201–226. 1888.

Extracts from publications of the Peter Redpath Museum, September, 1888.

In part as "On new facts relating to Eozoon canadense," Geol. Magazine, decade 3, vol. 5, pp. 49–54, plate. 1888.

Review of paragraph 9, on upper Laurentian, by A. R. C. Selwyn, Science, vol. 11, p. 146, ½ col. 1888.

Includes incidental references to containing beds at several localities, beds of fragmental Eozoon, the relations of the limestones of the

DAVIS, William Morris—Continued.

middle Laurentian, the aqueous origin of the greater part of the upper Laurentian, the equivalency of some of the crystalline rocks west of Lake Superior with the upper Laurentian of St. Jerome, and some instances of rock lamination.

—— Notes on fossil woods and other plant remains from the Cretaceous and Laramie formations of the western territories of Canada.

Canada, Royal Soc., Trans., vol. 5, section IV, pp. 31–37, 4°. 1888.

Abstract, Am. Geologist, vol. 1, pp. 195–197. 1888.

Includes references to localities, climatic conditions in later Cretaceous and early Tertiary times, the position of the Laramie of the Northwest, and the distinction between the lower and upper Laramie.

—— On the Eozoic and Paleozoic rocks of the Atlantic coast of Canada in comparison with those of western Europe and the interior of America.

Geol. Soc., Quart. Jour., vol. 44, pp. 797–817. 1888.

Abstracts, Geol. Magazine, 3d decade, vol. 5, pp. 331–332, 1888; Canadian Record Science, vol. 3, pp. 182–183, 230–231, 1888; Nature, vol. 38, p. 142, ½ col., 1888; Popular Science Monthly, vol. 36, p. 287, ½ p., 1889.

Subdivisions, relations, history, extent, and equivalency of Laurentian, Huronian, Cambrian, Ordovician, Silurian, Devonian, and Carboniferous systems.

—— [On nomenclature, subdivisions, characteristics, evidence of life and origin of some members of the Archean, origin of serpentines, classification of Archean eruptives, nomenclature of lower Paleozoic.]

International Congress of Geologists, Am. Committee Reports, 1888, A, p. 71, ½ p.

—— [On use of term "Taconic."]

International Congress of Geologists, Am. Committee Reports, 1888, B, p. 17, 1 line.

Am. Geologist, vol. 2, p. 207.

Expression of opinion.

—— On Nematophyton and allied forms from the Devonian (Erian) of Gaspé and Bay des Chaleurs. Introductory geological note.

Canada, Royal Soc., Trans., vol. 6, Section IV, pp. 27–36. 1889.

Includes a sketch of the stratigraphy of the region and table showing the equivalency of the Devonian beds with those of other localities.

DAWSON, J. William—Continued.

—— Supplemental note to a paper on the rocks of the Atlantic coast of Canada.

Geol. Soc., Quart. Jour., vol. 45, p. 80, ½ p. 1889.

Reference to the position of the *Olenellus* fauna and to the bearing of new evidence on this point on the geologic conditions during Lower Cambrian and late pre-Cambrian times.

—— Note on Balanus Hameri in the Pleistocene at Rivière Beaudette, and on the occurrence of peculiar varieties of Mya arenaria and M. truncata in the modern sea and in the Pleistocene.

Canadian Record Science, vol. 3, pp. 287-292. 1889.

Brief reference to nature and equivalency of the containing beds.

—— Handbook of geology for the use of Canadian students, p. 250, Montreal. 1889.

—— and **DAWSON**, G. M. On Cretaceous plants from Port McNeill, Vancouver Island.

Canada, Royal Soc., Trans., vol. 6, Section IV, pp. 71-72.

Abstract, Canadian Record of Science, vol. 3, p. 167, ½ p. 1888.

Includes a description of the relations of the plant-bearing beds and statement in regard to their equivalency and age.

[**DAY**, David T.] Infusorial earth.

U. S. Geol. Survey, Mining Resources, 1887, p. 554, ½ p. 1888.

Notice of occurrence at Pope's Creek, Maryland, and Linkville, Klamath County, Oregon. Analyses of former by P. de P. Ricketts.

Delaware, Sand dunes of Lewes, ROTHROCK.

DEMING, J. L. See **HERRICK**, C. L. and **CLARKE**, E. S.

Denison University, Scientific Laboratories, Bulletin, vol. 2.

Clinton group of Ohio, FOERSTE.

Geological history of Licking County, HERRICK.

Geology of Michipiciton Bay, HERRICK, TIGHT and JONES.

—— vol. 3.

Clinton group of Ohio, FOERSTE.

Geology of Licking County, Ohio, HERRICK.

—— vol. 4.

Geology of Licking County, HERRICK.

Denison University, Scientific Laboratories, Bulletin, vol. 4—Continued.

Contact phenomena in South Carolina, RICHARDS.

DENNIS, D. W. The east-west diameter of the Silurian island about Cincinnati.

Am. Naturalist, vol. 22, p. 94, 8 lines. 1888.

Abstract of paper read to Indiana Academy of Science.

Reference to occurrence of beds indicating position of shore line.

Deutsche Geologische Gesellschaft, Zeitschrift, vol. 40.

Jorullo in Mexico, FELIX.

DERBY, Orville A. On the occurrence of monazite as an accessory element in rocks.

Am. Jour. Sci., 3d series, vol. 37, pp. 109-113. 1889.

Announcement of discovery of monazite and zircon as constituents of various granite rocks in Brazil.

Devonian.

Alabama, SPENCER, J. W.

Canada, At-ta-wa-pish-kat and Albany rivers, BELL.

Baffin Land, BOAS.

Eozoic and Paleozoic of Canada, DAWSON, J. W.

explorations in portions of New Brunswick, BAILEY and MCINNES.

gypsum in northern Manitoba, TYRRELL.

natural gas in Quebec, LAFLAMME.

Nematophyton from Gaspé, DAWSON, J. W.

northern Maine and New Brunswick, BAILEY.

northern part of the Dominion of Canada, DAWSON, G. M.

Nova Scotia, faults and foldings in Pictou coal field, GILPIN.

Nova Scotia, Guysborough, Antigonish, and Pictou, FLETCHER.

Ontario iron ores, IVES.

Ontario petroleum field, BELL.

Ontario, range of Hamilt n fossils, CALVIN.

organisms in southern New Brunswick, MATTHEW.

Passamaquoddy Bay region, MATTHEW.

Red River Valley, Manitoba, MCCHARLE.

Devonian—Continued.
Canada—Continued.
relations between geology of Maine and New Brunswick, BAILEY.
Rocky Mountains near the 51st parallel, MCCONNELL.
well at Port Colborne, MCRAE.
Georgia, SPENCER, J. W.
Indiana, GORLEY. THOMPSON, M.
Iowa, Devonian faunæ, WILLIAMS, H. S.
general description, WEBSTER.
Johnson County, WEBSTER.
Muscatine County, CALVIN.
Rockford shales, WEBSTER.
southeastern Iowa, GORDON.
well at Keokuk, GORDON.
well at Davenport, TIFFANY.
well at Washington, CALVIN.
Kansas, Leavenworth well, JAMESON.
Kentucky, Bath and Fleming counties, LINNEY.
Clarke, Lincoln, Mercer, LINNEY.
central Kentucky, LINNEY.
Garrard County, LINNEY.
Henry, Selby, and Oldham counties, LINNEY.
Jackson purchase region, LOUGHRIDGE.
Marion County, KNOTT.
Nelson County, LINNEY.
Oriskany of eastern, PROCTOR.
Ohio Valley, SHALER.
Pound Gap region, CRANDALL.
rocks of central Kentucky, LINNEY.
Maine, Aroostook County, BAILEY.
Eastport, SHALER.
northern Maine, BAILEY.
Minnesota, natural gas wells, WINCHELL, N. H.
maps, UPHAM.
artesian wells, HALL, C. W.
Missouri, Chouteau group, ROWLEY.
history of Ozark uplift, BROADHEAD.
Macon County, MCGEE.
Montana, Gallatin region, HAYDEN. WALCOTT.
Nebraska, well at Lincoln, RUSSELL, J. W.
well in Pawnee County, RUSSELL, J. W.
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Includes brief reference to geologic relations of beds in which it occurs.

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Popular Science Monthly, vol. 32, p. 419, 10 lines. 1888.

Abstract of U. S. Geol. Survey, Bulletin No. 33, described in the 1886 bibliography.

—— The latest volcanic eruption in northern California and its peculiar lava.

Am. Jour. Sci., 3d series, vol. 33, pp. 45–50. 1887.

Abstract, Am. Geologist, vol. 1, p. 126, ½ p. 1888.

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—— Peridotite of Elliott County, Kentucky.

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(By Geo. H. Williams), Neues Jahrbuch, 1887, vol. 2, pp. 475–476.

Describes its occurrence, micro-petrography, structure, and alteration. Discusses its nature, origin, and relations to the associated Carboniferous sandstones. Quotes Crandall's description of the region.

—— Supplementary note on the peridotite of Elliott County, Kentucky.

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Entirely petrographic.

—— [Report on petrography of peridotite from Douglas County, Oregon, and Webster, North Carolina.] See **CLARKE**, F. W., on nickel ores from Oregon.

—— and **KUNZ**, George F. Is there a diamond field in Kentucky?

Science, vol. 10, pp. 140-142. 1887.

Describe and figure the peridotite outcrops, call attention to an exposure of contact with the Carboniferous shales, and discuss the possibilities of the occurrence of diamonds.

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Analyses and letter from A. Pugh on number of beds and dip.

DRUMMOND, A. T. The distribution and physical and past geological relations of British North American plants.

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Discusses probability of a Tertiary land connection between Asia and North America, and post-Tertiary changes in North American physiography which would impede the eastward extension of plants. Advances botanical evidence in opposition to the idea of regional glaciation in Canada, and argues in favor of local glaciation. Incidentally refers to climatic conditions in later Cretaceous and Eocene times indicated by the flora.

—— The prairies of Manitoba.

Canadian Record Science, vol. 3, pp. 39–43. 1888.

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Abstract, Popular Science Monthly, vol 35, pp. 422–423, ½ p. 1889.

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—— The great lake basins of the St. Lawrence.

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Abstracts, Science, vol. 13, p. 32, ¾ col. 1889. Am. Geologist, vol. 3, pp. 197-199, ½ p. 8. 1889.

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DUNN, Russell L. Drift mining in California.

California, Eighth Report of State Mineralogist, pp. 736–770. 1888.

Includes references to the ancient drainage systems to which the gold-bearing gravels belong. Discusses relations, sequence, and extent of some of the lava flows by which this drainage system was displaced.

DUTTON, Clarence E. Mount Taylor and the Zuñi Plateau.

U. S. Geol. Survey, Sixth Report, J. W. Powell, 1884'-85, pp. 105-198, pls. 11-22. 1885.

Abstracts, Am. Jour. Sci., 3d series, vol. 34, pp. 155-198, pls. 11-12; Science, vol. 10, pp. 317-318. 1887.

Describes the High Plateau country as a whole, the formations of northwestern New Mexico, extending from upper Carboniferous to Wahsatch sandstone, the uplift or "swell" of the Zuñi Plateau, the Zuñi uplift, Mount Taylor and vicinity with its great middle Tertiary lava flows and old vents, the newer lavas of the San José valley region and their source, and the areal geologic features in general. Discusses questions of synchronism and stratigraphy, especially in regard to the Jura and Trias, the mechanism of the faults on the southwest side of the Zuñi Plateau, the relations of the Archean to the adjacent Carboniferous rocks along the axis of the Zuñi Plateau, and the age, extent, and mode of extrusion of the lavas of Mount Taylor and vicinity, and of the more recent flows. Chapter v consists of a general discussion of the geologic history of the High Plateau and adjoining regions.

—— The submerged trees of the Columbia River.

Science, vol. 9, pp. 82-84. 1887.

Describes evidence of a slight post-glacial transverse anticlinal as the cause of damming.

—— [On geologic nomenclature in general, and the classification, nomenclature, and distinctive characteristics of the pre-Cambrian formations, and the origin of serpentines.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 71-73.

[——] [On the use of the term Taconic.]

International Congress of Geologists, Am. Committee Reports, 1888, B., p. 17, 1 line.

Am. Geologist, vol. 2, p. 207. 1888.

Statement of opinion.

—— Report—Division of volcanic geology.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 97-103. 1888.

Includes a general description of the geology of the region between the Cascade Ranges and the Sierra Nevada, the southern part of the Cascade Ranges, and the region westward, including the Coast Ranges in western Oregon and northwestern California.

—— On some of the greater problems of physical geology.

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Discussion of earth crust deformation.

DWIGHT, William B. Palæontological observations on the Taconic limestones of Canaan, Columbia County, New York. (Abstract.)

American Naturalist, vol. 21, pp. 270-271. 1887.

Describes Trenton and Calciferous fossiliferous limestone exposures.

—— Primordial rocks of the Wappinger Valley limestones.

Vassar Brothers' Inst., Trans., vol. 4, pp. 130-141, Pl. 1. 1887.

Republication of a paper entitled "Discovery of fossiliferous Potsdam strata at Poughkeepsie, New York," in Am. Jour. Sci., 3d series, vol. 31, pp. 125-133, pl. 6, and described in the bibliography for 1886.

—— Primordial rocks of the Wappinger Valley limestones and associated strata.

Vassar Brothers' Inst., Trans., vol. 4, pp. 206-214. 1887. See, also, Am. Jour. Sci., 3d series, vol. 34, pp. 27-32. 1887.

Calls attention to several new localities of fossiliferous Potsdam and discusses the relations of the several belts of this formation to each other and to the associated limestones. Announces the discovery by himself and Walcott of middle Cambrian remains in the quartzites and limestone on the flanks of Stissing Mountain and its vicinity, and describes the structure of the region. Gives a general résumé of the formations occurring in Dutchess County, New York.

—— [Remarks on crustal plication in continental elevation.]

Vassar Brothers' Inst., Trans., vol. 4, pp. 271-273. 1887.

Discusses Warring's address on the evolution of continents.

—— Recent explorations in the Wappinger Valley limestone of Dutchess County, New York. No. 6. Discovery of additional fossiliferous Potsdam strata and pre-Potsdam strata of the Olenellus group, near Poughkeepsie, New York.

Am. Jour. Sci., 3d series, vol. 34, pp. 27-32. 1887.

Essentially similar to "Primordial rocks of the Wappinger Valley limestones and associate strata," which antedates it.

—— Recent explorations in the Wappinger Valley limestones and other formations of Dutchess County, New York. No. 7. Fossiliferous strata of the paradoxides zone at Stissing. No. 8. Dis-

DWIGHT, William B.—Continued.

covery of Calciferous fossils in the Millerton-Fishkill limestone belt; also in a belt near Rhinebeck.

Am. Jour. Sci., 3d series, vol. 38, pp. 139–153, pl. 6. 1889.

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Edinburgh Geological Society, Transactions, vol. 5.

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Am. Jour. Sci., 3d series, vol. 38, pp. 313–321. 1889.

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A discussion of the classification of the middle Cretaceous in the West and Northwest, including a general description of the characteristics of its several members.

—— On some stratigraphical and structural features of the country about Denver, Colorado.

Colorado Sci. Soc., Proc., vol. 3, pp. 86–118, 1889.

Description of the Archean and Triassic to Tertiary formations, coals, unconformities, faults, flexures, and topographic characteristics, discussion of various questions of equivalency and classification, and sketch of geologic history of the region.

Elisha Mitchell Scientific Society Journal, 1888, part 2.

Mica mining in North Carolina, PHILLIPS.

ELLS, R. W. Report on the geology of a portion of the eastern townships, relating more especially to the counties of Compton, Stanstead, Beauce, Richmond, and Wolfe.

Canada, Geol. and Nat. Hist. Survey, Report, 1886, part J, pp. 70, plates, map 5 in atlas. 1887.

ELLS, R. W.—Continued.

Abstracts, Ibid., part A, pp. 28–36. Geol. Magazine, III, vol. 6, pp. 134–135. 1889.

Description of Silurian, Cambro-Silurian, Cambrian, pre-Cambrian, granites, diorites, serpentines, drifts and structure, and discussion of the age, history, equivalency, and structural relations of the several formations, and the nature of glaciation in the region. List of glacial striæ. Accompanied by a colored geologic map.

—— Elementary lecture on geology.

Ottawa Naturalist, vol. 2, pp. 117–134. 1889.

An account of the history of geologic science and sketch of geologic history of Canada, in which are included brief discussions of the nature and relations of the pre-Cambrian crystallines and of the conditions during the Quaternary.

—— Notes on the geological relations and mode of occurrence of some of the more important economic minerals of eastern Quebec.

Ottawa Naturalist, vol. 3, pp. 45–57. 1889.

Includes a brief general account of the geology of the region, incidental references to geologic features, and allusions to age of the gold-bearing series and to occurrence and relations of the serpentines.

EMERSON, B. K. The Connecticut Lake of the Champlain period, north of Holyoke.

Am. Jour. Sci., 3d series, vol. 34, pp. 404–405, ½ p. 1887.

Abstract of paper on Hampshire County, Massachusetts. Describes the outline of the lake and its deposits. Discusses the duration of the lake and the remoteness of the glacial period.

—— [On the use of the term "Taconic."]

International Congress of Geologists, Am. Com. Reports, 1888, B, p. 17, 2 lines.

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Expression of opinion.

—— Topography — geological features [etc.].

Massachusetts, Hampshire County Gazetteer, 1654–1887, by W. B. Gay, Syracuse, N. Y., pp. 10–22. 1888.

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U. S. Geol. Survey, Sixth Report, 1884–'85, pp. 62–67. 1885.

Outlines evidence in the Gunnison district and elsewhere, indicating a Jurassic and a Carboniferous unconformity in the Rocky Mountain region. Describes the age and extent of the uplifts.

—— [On the use of the term "Taconic."]

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—— Geology and mining industry of Leadville, Colorado. U. S. Geol. Survey, Monographs. No. 12, 2 vols. 4°: vol. 1, pp. xxix, 1–362, pls. 1–21; vol. 2, pp. 363–770, pls. 22–45, and folio atlas of 35 plates. Washington, 1886.

Abstracts, Science, vol. 11, pp. 18–19, 1889; Am. Geologist, vol. 1, pp. 194–195, 1888; Nature, vol. 39, pp. 484–485, 1889; Scottish Geogr. Mag., vol. 5, pp. 198–202, 1889.

Detailed description of the geology of the Mosquito Range and of Leadville and vicinity. Discusses geologic history; stratigraphy and structural relations; origin of dolomites; occurrence of serpentine in Silurian rocks and elsewhere; the relations of the faults and flexures and their development; the structure of the Rocky Mountains and Basin Ranges; the succession, age, extent, texture, and composition of the eruptive rocks, the mechanism and extent of intrusion, the distribution of intrusives in the Rocky Mountains, the occurrence of laccolites in the Henry Mountains and elsewhere; contact, metamorphism, classification of ore deposits in general, and the relations, composition, and genesis of the Leadville deposits. Accompanied by maps, plans, and sections, and includes: Appendix A, Petrography, by Whitman Cross; B, Chemistry, by W. F. Hillebrand, and C, Metallurgy, by Antony Guyard.

—— Notes on some Colorado ore deposits.

Colorado Sci. Soc., Proc., vol. 2, part 2, pp. 85–105. 1887.

Considers the relation of faults to ore deposits, describing some features of the Leadville, Carbonate Hill, and San Juan regions.

EMMONS, S. F.—Continued.

Discusses some metamorphic changes in the San Juan region and secondary alteration of ore deposits in general, and as observed at Red Cliff and Leadville.

—— Notes on the geology of Butte, Montana.

Am. Inst. Mining Engineers, Trans., vol. 16, pp. 49–62. 1887.

Describes the topography, mineral deposits and characteristics, and distribution of the rocks. Discusses the origin of the depression in which Butte is situated, the history of its ores, and the relations of the fissures. The genesis of the ores is also discussed by R. W. Raymond, pp. 11–14.

—— The submerged trees of the Columbia River.

Science, vol. 9, pp. 156–157. 1887.

Discusses the cause of the damming of the Columbia River, restating an explanation previously published, and opposing Dutton's theory of a transverse anticlinal.

—— Structural relations of ore deposits.

Am. Inst. Mining Engineers, Trans., vol. 16, pp. 804–839. 1888.

Discussion of causes, nature, and relations of structural and physical conditions affecting the transportation and deposition of mineral matter. References to relations of faults and mineral deposits in various parts of Colorado and at the Ontario mine, Utah.

—— On the origin of fissure veins.

Colorado Sci. Soc., Proc., vol. 2, pp. 189–208. 1888.

Discussion of the physical and structural conditions affecting the transportation and deposition of mineral matters and the origin and relations of fissures and planes produced by dynamic movements.

—— On glaciers in the Rocky Mountains.

Colorado Sci. Soc., Proc., vol. 2, pp. 211–227. 1888.

Consists mainly of a discussion of distinctions between glaciers and névé and an account of the existence of glaciers in the Rocky Mountains and the Sierra Nevada. Refers also to the results of former glaciation in the same regions.

—— Preliminary notes on Aspen, Colorado.

Colorado Sci. Soc., Proc., vol. 2, pp. 251–277. 1888.

Account of geologic relations of the region and discussion of the structure of Aspen Mountain, the dolomitization of the limestones, and evidence bearing on the sequence of porphyry intrusions, faulting, and ore deposition. Reference to evidences of glaciation.

—— [On subdivisions, nomenclature, origin of some members, and characteris-

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tics of the Archean, classification of eruptives, and origin of serpentines.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 58–61.

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International Congress of Geologists, Am. Committee Report, 1888, B, p. 17, 2 lines.

ENDLICH, F. M. The origin of the gold deposits near Ouray, Colorado.

Eng. and Mining Jour., vol. 48, p. 335, ⅛ p. 4°. 1889.

Includes a general description of the geologic features of the region.

ENGINEERING AND MINING JOURNAL. Gogebic iron mines.

Eng. and Mining Jour., vol. 43, p. 182, 4°. 1887.

Description of nature and structure of ore beds and associated strata.

—— The "Dauntless" core drill.

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Gives columnar section of coal measures in drill-hole at Saybrook, Illinois.

—— The Sylvanite mine, Colorado.

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Brief reference to presence of associated diorite and highly altered sediments.

—— Zinc mining in Arkansas.

Eng. and Mining Jour., vol. 47, p. 431, ⅛ p. 4°. 1889.

Includes a brief general sketch of geology of zinc region in Marion County.

Engineering and Mining Journal, vols. 43 and 44.

American chemical industries, salt, WYATT.
Battle Mountain mining district, OLCOTT.
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Am. Geologist, vol. 2, pp. 331–334. 1888.
Description and discussion of mode of origin and equivalency with other similar deposits.

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Am. Inst. Mining Engineers, Trans., vol. 16, pp. 33–35. 1887.
Describes decomposed andesites, trachyte, and limestone with sulphur impregnations.

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Deutsche Geol. Gesell., Zeit., vol. 40, pp. 355–357. 1888.

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—— Across the Santa Barbara Channel.

Am. Naturalist, vol. 23, pp. 211–217, 387–394. 1889.
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FLETCHER, Hugh. Report on geological surveys and explorations in the counties of Guysborough, Antigonish, and Pictou, Nova Scotia, from 1882 to 1886.

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Geol. Magazine, III, vol. 6, pp. 136–137, ½ p. 1889.

Description of formations from pre-Cambrian to Permian, superficial deposits, volcanic and metamorphic rocks, structural relations and overlaps, and discussion of equivalency, age, history, and distribution of the formations at various localities. Soils.

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Am. Geologist, vol. 2, pp. 412–419. 1888.

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—— The Clinton group of Ohio, part IV.

Denison Univ., Sci. Laboratories, Bull., vol. 3, pp. 3–12. 1888.

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—— The paleontological horizon of the limestone at Nahant, Massachusetts.

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Am. Geologist, vol. 4, pp. 367–371. 1889.

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Gives records of some deep borings and comments on the more noteworthy stratigraphic evidence they present.

GRANT, Uly. S. Report of geological observations made in northeastern Minnesota during the summer of 1888.

GRANT, Uly. S.—Continued.

Minnesota, Geol. and Nat. Hist. Survey, Seventeenth Report, pp. 149–215. 1889.

Itinerary notes, mainly on the region from Vermilion Lake east to Gunflint Lake, and relating mostly to relations of the gabbro and red syenite, and magnetite quartzite at Frazer and Thomas lakes.

GRATACAP, Louis P. [Microscopic nature and origin of Staten Island serpentines.]

Staten Island, Nat. Sci. Assoc., Proc., May 14, 1887, 2d leaf.

Discusses the several theories of serpentine formation and presents facts indicative of the derivation from hornblendic rocks of the serpentine of Staten Island.

—— Preliminary list of Paleozoic fossils found in the drift of Staten Island.

Staten Island, Nat. Sci. Assoc., Proc., [Jan. 8, 1887,] extra, No. 6, 2 leaves.

From Potsdam to upper Helderberg.

—— The eozoonal rock of Manhattan Island.

Am. Jour. Sci., 3d series, vol. 33, pp. 374–378. 1887.

Describes the occurrence and literature of the belt of serpentines on New York Island, giving an account of their micropetrography and discussing the origin of their constituent minerals. Evidence is presented which is thought to indicate the probable inorganic character of the eozoonal structure.

—— [Notice of occurrence of bowlder of Oriskany sandstone on Staten Island.]

Staten Island, Nat. Sci. Assoc., Proc., March, 1889.

Am. Naturalist, vol. 23, pp. 549–550, ¾ p. 1889.

Includes a list of the twenty species of fossils which it contained.

GREGG, A. Economic minerals of San Saba County.

Texas, Geol. and Mineralogical Survey, First Report, 1888, pp. 74–76. 1889.

Includes geologic notes, mainly in regard to the marbles near San Saba.

GREEN, W. Spotswood. Explorations in the glacier region of the Selkirk range, British Columbia.

Royal Geog. Soc., Proc., vol. 11, pp. 153–169. 1889.

Includes some brief references to nature of rocks, terraces, and evidence of glaciation.

GRESLEY, W. S. Formation of coal-seams.

Eng. and Mining Jour., vol. 45, p. 338, ¼ col, 4°. 1888.

Discusses method of accumulation of materials.

H.

[HAGGIN, J. B.] Record of strata in artesian well. [Kern County.]

California, Sixth Annual Report of the Mineralogist, part I, pp. 56–57. 1886.

Through gravels, sands, and clays to 650 feet in one well and 472 feet in the other.

HAGUE, Arnold. Report . . . Yellowstone Park division.

U. S. Geol. Survey, Sixth Annual Report, 1884-85, pp. 54–59. 1885.

Incidentally refers to some geologic features of the park.

—— Geological history of the Yellowstone National Park.

Am. Inst. Mining Engineers, Trans., vol. 16 pp., 783–803. 1888.

Abstract, Popular Science Monthly, vol. 36, pp. 282–283, ½ p. 1889.

References to geology of surrounding ranges, pre-Tertiary uplifts, glaciation, rock decomposition, and antiquity and rate of growth of hot spring deposits, and sketch of Tertiary volcanic history of the park.

—— [On the Archean and its subdivisions.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 66–67.

Discusses the distinctness of the Archean as a system, separateness of the Huronian, and the subdivision and classification of eruptives in the Archean.

[——] [On the use of the term "Taconic."]

International Congress of Geologists, Am. Committee Reports, 1888, B, p. 17, 2 lines.

Am. Geologist, vol. 2, p. 207. 1888.

Suggestion in regard to its application.

—— Notes on the occurrence of a leucite rock in the Absaroka range, Wyoming Territory.

Am. Jour. Sci., 3d series, vol. 38, pp. 43–47. 1889.

Abstract, Am. Naturalist, vol. 23, p. 811, ½ p. 1889.

Account of a bowlder of leucite rock, and discussion of its petrography, composition, and origin. Includes a petrographic description by J. P. Iddings, an analysis by J. E. Whitfield, and a list of localities of leucite-bearing rocks in various parts of the world.

HALL, C. W. A brief history of copper mining in Minnesota.

Minnesota, Acad. Sci., Bull., vol. 3, part 1, pp. 105–111. 1889.

Prefaced by an account of the Keweenawan formation, and brief discussion of its extent in Minnesota.

HALL, C. W.—Continued.

—— The lithological characters of the Trenton limestone of Minneapolis and St. Paul, with a note on the borings of the West Hotel artesian well.

Minnesota, Acad. Sci., Bull., vol. 3, part 1, pp. 111–124, pl. 1. 1889.

Detailed description of Trenton and the underlying St. Peters sandstone in the vicinity of the city. Analyses. Well record. Reference to glacial striæ and thickness of drift.

—— The geological conditions which control artesian well borings in southeastern Minnesota.

Minnesota, Acad. Sci., Bull., vol. 3, part 1, pp. 128–143. pl. 2. 1889.

Includes an account of the stratigraphy of the region, and records of a dozen wells.

—— The distribution of the granites of the Northwestern States and their general lithologic characters. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 37, pp. 189–190. 1889.

List of localities, summary of petrographic characteristics, and reference to age.

—— Field notes on the geology of the Mohawk valley. See [**Beecher, C. E., and Hall, C. E.**†]

HALL, James. Report on building stones.

New York, Thirty-ninth Report State Museum of Nat. Hist., 1885, pp. 136–227. 1886.

Description of some of the gneisses, granites, and marbles of New York and New England and the limestones and sandstones of New York. Discusses the qualities, selection, and causes of decay in building stones.

—— Report of the State Geologist.

New York, Thirty-ninth Report State Museum of Nat. Hist., 1885, pp. 226–227. 1886.

New York, Sixth Report of the Geologist, 1886, pp. 5–9. 1887.

Includes an account of contacts of Laurentian gneisses and overlying rocks near Little Falls, and a statement in regard to the horizon of the Oneonta sandstone.

—— [On the nomenclature of the American lower Paleozoic.]

International Congress of Geologists, Am. Committee Reports, 1888, B, p. 10, ½ p.

Am. Geologist, vol. 2, p. 200. 1888.

On the adoption of exclusively European terms, and the application of the term "Taconic."

[**HANKS**, Henry.] Building stones and building materials in California.

California, Sixth Annual Report of the Mineralogist, part 1, pp. 16–34. 1886.

Description of well known building stones and of California localities. Gives partial analyses of a dunyte from San Diego County and a sandstone from Santa Barbara.

[——] Mount St. Helena.

California, Sixth Annual Report of the Mineralogist, part 1, pp. 78–79, 2 plates. 1886.

Description of outcrop of columnar basalt. Considers the mountain an old volcano, but finds no evidence of a crater.

[——] San Diego County.

California, Sixth Annual Report of the Mineralogist, part 1, pp. 80–90, map. 1886.

Incidental geologic and mineralogic notes. Describes fold in slates in mine at Banner. Accompanied by a colored geologic map of the county, provisionally illustrating the distribution of Quaternary, Tertiary, Permo-Carboniferous, and Archean.

[——] California minerals.

California, Sixth Annual Report of the Mineralogist, part 1, pp. 91–141. 1886.

Includes descriptions of some localities of lignite, various kinds of quartz, limestones, and serpentines.

—— On the occurrence of hanksite in California.

Am. Jour. Sci., 3d series, vol. 37, pp. 63–66. 1889.

References to various localities and record of 300-foot bore-hole into volcanic sand, and lacustrine deposits underlying Borax Lake.

HARDEN, Oliver B. See **PROSSER**, A. G., and.

HARKER, Alfred. The Cortlandt rocks.

Geol. Magazine, 3d decade, vol. 4, pp. 431–432. ½ p. 1887.

Calls attention to Callaway's oversight of the present views of Dana and Williams in regard to the probable eruptive nature of some of the Cortlandt rocks which Dana at first considered metamorphic.

HARROD, B. M. Archean rocks in Texas.

New Orleans Acad. Sci., Papers, vol. 1, No. 2, pp. 131–133. 1888.

Brief references to outcrops and characteristics.

Harvard, Museum Comparative Zoölogy, Bulletin, vol. 16.

Dike of diabase in Boston basin, HOBBS.

Cambrian district of Bristol County, Massachusetts, SHALER.

Harvard Museum Comparative Zoölogy, Bulletin, vol. 16—Continued.

Fossil plants from Golden, Colorado, LESQUEREUX.

Faults in Trias near Meriden, Connecticut, DAVIS.

Triassic trap sheets of Connecticut valley, DAVIS and WHITTLE.

—— **vol. 17.**

Coral reefs of Hawaiian Islands, AGASSIZ.

Harvard Museum Comparative Zoölogy, Memoirs, vol. 16, No. 2.

Connection of eastern and western coal fields, Ohio valley, SHALER.

Hawaiian Islands.

coral reefs, AGASSIZ.

genesis, HITCHCOCK.

Halema'uma'u and its débris cone, DANA, J. D.

Mount Loa craters, BAKER. DANA, J. D. MERRITT.

Petrography, DANA, E. S.

HAWORTH, Erasmus. A contribution to the Archean geology of Missouri.

Am. Geologist, vol. 11, pp. 280–297, 363–382, part 1. 1888.

Abstracts, Johns Hopkins Univ., Circulars, vol. 7, pp. 70–71, No. 65. 4°. 1888. Am. Naturalist, vol. 22, pp. 739, 838. ½ p.

General description of relations of the massive rocks to each other and to the stratified rocks, and petrographic description of granites, porphyries, and diabases.

HAY, O. P. On the manner of deposit of the glacial drift.

Am. Jour. Sci., 3d series, vol. 34, pp. 52–58. 1887.

Statement of the views of Dana, the Geikies, Newberry, and N. H. Winchell. Discusses the action of the glacier on its bed, in general and under varying circumstances, and the mode of accumulation of drift-material at its base and in the terminal moraine.

—— The northern limit of the Mesozoic rocks in Arkansas.

Arkansas, Geol. Survey, Report for 1888, vol. 2, pp. 261–290. 1888.

Descriptions of outcrops, and relations of the Cretaceous in the vicinity of the Mesozoic-Paleozoic boundary line.

—— A geological section in Wilson County, Kansas.

Kansas Acad. Sci., Trans., vol. 10, pp. 6–8, plate. 1888.

Discussion of rate of dip, evidence of a fault, and equivalency of the Dun limestone with the Humboldt limestone.

HAY, O. P.—Continued.

—— Report on geology.

Kansas Acad. Sci., Trans., vol. 10, pp. 21–22. 1888.

Discussion of the eastern extension of the Tertiary in southern Kansas, and the equivalency and boundary of the red rocks and gypsum in the region extending from Comanche County to Medicine Lodge.

—— Natural gas in eastern Kansas.

Kansas Acad. Sci , Trans., vol. 10, pp. 57–62, plate. 1888.

Abstract from Fifth Report of State Board of Agriculture.

Reference to geologic position of gas-yielding beds. Gives sections at Fort Scott, and refers to the stratigraphic and structural relations in that vicinity. Partial section from Fort Scott, Kansas, to Novada, Missouri, on plate.

—— Note on a remarkable fossil.

Kansas Acad. Sci., Trans., vol. 10, pp. 128–129, ½ p., plate. 1888.

Includes brief discussion of the derivation of the enclosing concretion in its bearing on the location of the former eastern boundary of the Cretaceous.

—— Horizon of the Dacotah lignite.

Kansas Acad. Sci., Trans., vol. 11, pp. 5–8. 1889.

Abstract, Am. Geologist, vol. 5, pp. 249–250, 5 lines. 1890.

References to the relations, stratigraphy and distribution of the Dacotah group, and discussion of evidence bearing on the horizon of the lignitic beds.

—— Lecture. The geology of Kansas.

Kansas Acad. Sci., Trans., vol. 11, pp. 35–37. 1889.

References to distribution and relations of the Jura-Trias, Cretaceous, and Tertiary.

—— The Triassic rocks of Kansas. [Abstract.]

Kansas Acad. Sci., Trans., vol. 11, pp. 38–39, ½ p. 1889.

Abstract, Am. Geologist, vol. 5, p. 250, 8 lines. 1890.

References to their relations to the Permo-Carboniferous and absence of unconformity at their base.

—— Recent discoveries of rock salt in Kansas. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 37, pp. 184–185. 1889.

Statements in regard to its stratigraphic position and relations, and brief sketch of the Permian-"Dacotah" history of the region.

—— and **THOMPSON**, A. H. Historical sketch of geological work in the State of Kansas.

HAY, O. P.—Continued.

Kansas Acad. Sci., Trans., vol. 10, pp. 45–52. 1888.

Statements of the conclusions of each observer, and description of some unpublished papers in which information is given in regard to the eastern dip of the strata in the eastern part of the State, and the now known order of Kansas formations.

HAYDEN, F. V. Report . . . . . Montana division.

U. S. Geol. Survey, Sixth Report, J. W. Powell, 1884-'85, pp. 48–53. 1885.

Statement of results of studies in the region between the Bridger or East Gallatin range and the three forks of the Missouri Briefly describes the structure and stratigraphy of the several formations—including the newly discovered Devonian—the lake deposits of the Gallatin valley, and the drift.

—— Report . . . . . Montana division of geology.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 85–87. 1888.

Reference to relations of formations from Cambrian to Carboniferous and coals, and evidence of glacial action in the Gallatin range region, and to the volcanic constituents, age, origin, and relations of the lake beds of Gallatin valley.

HEADDEN, William P. [Notice of a thin bed of infusorial earth in west Denver.]

Colorado Sci. Soc., Proc., vol. 2, p. 183, ½ p. 1888.

HEILPRIN, Angelo. Explorations on the west coast of Florida and in the Okeechobee wilderness, with special reference to the geology and zoölogy of the Floridian peninsula.

Wagner Inst., Trans., vol. 1, pp i–viii, 1–134, pls. II, 1–19. 1887.

Abstracts, Am. Jour. Sci., 3d series, vol. 34, pp, 230–232. 1887. Popular Science Monthly, vol. 33, p. 418, ½ p. 1887.

Describes outcrops and occurrence of fossils. Summarizes observations on rocks of Homosassa, Cheeahowiska, Pithlachascootie, Manatee, and Caloosahatchee rivers, Tampa Bay, Hillsboro, and Sarasota Bay. Discusses literature, extent, equivalency, and paleontology of the subdivisions of the Tertiary; the coral-reef theory, and the general geologic history of the peninsula. Gives a table showing the relations of the "Atlantic and Gulf coast Tertiaries of the United States."

—— [On the classification of the Tertiary deposits.]

International Congress of Geologists, Am. Committee Reports, 1888, F, pp. 12–14.

HEILPRIN, Angelo—Continued.

Am. Geologist, vol. 2, pp. 278–280. 1888.

Discussion of upper limit of Tertiary and nomenclature.

[——] [Remarks on P. R. Uhler's paper on the Alburipean and associated formations in Maryland.]

Am. Phil. Soc., Proc., vol. 25, p. 54, ½ p. No. 127. 1888.

Expression of opinion that part of the "Alburipean" is Paleozoic, and in regard to the age of the Potomac formation.

—— The Miocene mollusca of the State of New Jersey.

Philadelphia Acad. Sci., Proc., 1887, p. 397.

Lists of fossils, notes on new and old species, and expression of opinion regarding age and equivalency of the Miocene members at Shiloh and in the Atlantic City well.

[——] Determination of the age of rock deposits.

Philadelphia Acad. Sci., Proc., 1887, p. 395.

Discussion of rates of deposition.

—— The classification of the post-Cretaceous deposits.

Philadelphia Acad. Sci., Proc., 1888, pp. 314–322.

Review of faunal relations and equivalency of the Tertiary formations mainly in the United States; and discussion of the value of the faunal element in geologic chronology.

—— The Bermuda Islands; a contribution to the physical history and zoölogy of the Somers Archipelago, with an examination of the structure of coral reefs, pp. 231, pls. 17. Philadelphia. 1889.

Includes an account of their geology and physiography, a discussion of the coral-reef problem, and a review of recent literature on coral reefs.

—— On Archean. See **FRAZER**. Report on the Archean.

HENRICH, Carl. The San Pedro copper mine in New Mexico.

Eng. and Mining Jour., vol. 43, p. 183. 4°. 1887.

Statement of character and dip of containing limestones.

—— The copper ore deposits near Morenci, Arizona.

Eng. and Mining Jour., vol. 43, pp. 202–203, 219–220. 4°. 1887.

Description of geologic relations of containing formations.

HENRICH, Carl—Continued.

—— Some forms of ore deposits in lime stone.

Eng. and Mining Jour., vol. 46, pp. 368–369. 4°. 1888.

Reference to attitude and evidences of internal erosion of limestones inclosing lead ores in Morgan County, Missouri, and Beaverhead County, Montana.

—— The United and Champion copper mines of New Zealand.

Eng. and Mining Jour., vol. 46, pp. 414–416. 4°. 1888.

Description of geologic relations of great "Serpentine" dikes in which the ores occur.

—— Metamorphism in rocks.

Eng. and Mining Jour., vol. 46, p. 461, ½ p. 4°. 1888.

Discusses the agency of highly heated underground waters under great pressure.

—— Notes on the geology and on some of the mines of Aspen Mountain, Pitkin County, Colorado.

Am. Inst. Mining Engineers, Trans., vol. 17, pp. 156–206. 1889.

Stratigraphy of beds from Cambrian to Carboniferous, structural relations, faults, intrusives, and ore deposits. Mainly a discussion of structural relations.

—— The Slaybach lode—a peculiar kind of fissure vein.

Eng. and Mining Jour., vol. 48, p. 27, ½ p. 4°. 1889.

Includes some statements in regard to relations of associated volcanic rocks, and dikes.

—— Is a faulted fissure always the oldest? A study of faults.

Eng. and Mining Jour., vol. 48, p. 159, ½ p. 4°. 1889.

Discussion of mechanism of crossed faults.

HERRICK, C. L. A sketch of the geological history of Licking County, accompanying an illustrated catalogue of Carboniferous fossils from Flint Ridge, Ohio.

Denison Univ., Bull., vol. 2, pp. 5–68, pls. I–VI, pp. 144–148. 1887.

Detailed description of the geologic relations, the outcrops, structure, and characteristics of the Waverly and immediately overlying rocks. Discusses the mode and rate of deposition of the formations, the origin of their materials, and their paleontologic relations. Gives structural and columnar sections.

—— The geology of Licking County, Ohio, part III.

HERRICK, C. L.—Continued.

Denison Univ., Bull., vol. 3, pp. 13–110, pls. I–XII. 1888.

Abstracts, Am. Jour. Sci., vol. 37, pp. 317–318, ½ p., 1889; Am Geologist, vol. 3, p. 50, ½ p. 1889.

Discussion of the stratigraphic position and range of the Waverly and description of its stratigraphy, paleontology, and inclination, and of evidence of local unconformity in the sub-Carboniferous at some points. List of fossils, pp. 27–37.

—— Geology of Licking County, part IV.

Denison University, Bull., vol. 4, pp. 11–60, 97–123. pls. I–XI. 1888.

Abstracts, Am. Jour. Sci., 3d series, vol. 37, pp. 317–318, ½ p., 1889; Am. Geologist, vol. 3, p. 50, ½ p. 1889.

Pages 11–60 and 114–123, descriptions and lists of fossils.

Pages 97–114, discussion of stratigraphy of Waverly and associated series.

—— Notes on the Waverly group in Ohio.

Am. Geologist, vol. 3, pp. 94–99, pls. I–IV. 1889.

Discussion of the equivalency, taxonomy, and paleontologic relations of the Waverly members.

—— **CLARKE**, E. S. and **DEMING**, J. L. Some American norytes and gabbros.

Am. Geologist, vol. 1, pp. 339–346, pl. 1888.

Discussion of the modifications induced in basic eruptives by the interpenetrated rocks and description of occurrence and petrography of olivine noryte and adjacent rocks near Marshall, North Carolina, the Duluth gabbros and the garnetiferous gabbros from Granite Falls, Minnesota. Review of Wadsworth on the origin of diorites.

—— **TIGHT**, W. G. and **JONES**, H. L. Geology and lithology of Michipicoton Bay.

Denison Univ., Bull., vol. 2, pp. 119–143, pls. 10–13. 1887.

Abstracts, Am. Jour. Sci., 3d series, vol. 34, p. 12, ½ p. 1887; Am. Naturalist, vol. 21, pp. 654–655, pls. 22–23, 1887, (by Herrick?)

After reviewing the work of previous observers, especially McFarlan, describe the geologic features of the region and the micro-petrography and mode of occurrence of a series of rock specimens. Discuss the nature, relative positions, stratigraphic and structural relations, variations and equivalency of the Laurentian, Huronian, and Keweenawan series. Illustrated by maps and structural and micro-rock sections.

HEWETT, G. C. The northwestern Colorado coal region.

Am. Inst. Mining Engineers, Trans., vol. 17, pp. 375–380. 1889.

HEWETT, G. C.—Continued.

Statement in regard to geologic horizon and distribution of the coals and the general stratigraphy of the region. Notice of very recent lava flows.

HICKS, Henry. The Cambrian rocks of North America.

Geol. Mag., 3d decade, vol. 4, pp. 155–158. 1887.

Summarization of Walcott's views on the use of the term Cambrian and the faunal, and stratigraphic relations and equivalency of the subdivisions of the formation.

—— [Remark on equivalency of the Huronian with the Pebidian.]

Geol. Soc., Quart. Jour., vol. 44, p. 817, ½ p. 1888.

HICKS, Lewis E. [Diatomaceous earth on North Loup River, Nebraska.]

Am. Geologist, vol. 1, p. 136, ⅛ p. 1888.

Notice of its occurrence and thickness.

—— Geyserite in Nebraska.

Am. Geologist, vol. 1, pp. 277–280, vol. 2, p. 437. 1888.

Reference to occurrences of volcanic dust in Nebraska, and extracts from "Physical geography and geology of Nebraska," 1890, by Samuel Aughey on polishing powders and supposed infusorial earth and geyser flocula.

—— The reef-builders.

Am. Geologist, vol. 1, pp. 297–305. 1888.

Discussion of the theories of Darwin and Murray.

—— [Volcanic dusts from Krakatoa, and from Nebraska and Kansas.]

Am. Geologist, vol. 2, p. 64, ½ p. 1888.

Reference to evidence of their volcanic nature.

—— [Quartzite between Niobrara and O'Neil, Nebraska, and its relation to the Valentine quartzite.]

Am. Geologist, vol. 2, pp. 351–352, ½ p. 1888.

Reference to occurrence of quartzite on road from Niobrara to O'Neil, Nebraska, and discussion of its age and equivalency with the Tertiary quartzite at Valentine, Nebraska.

—— Diatomaceous earth in Nebraska.

Am. Jour. Sci., 3d series, vol. 35, p. 86, ½ p. 1888.

List of species. Brief reference to mode of occurrence.

—— Soils of Nebraska as related to geological formations.

Am. Geologist, vol. 3, pp. 36–45. 1889.

Includes a preliminary geologic map and sketch of the geology of the State.

HILGARD, E. W. The equivalence in time of American marine and intra-continental Tertiaries.

Science, vol. 9, pp. 525–536. 1887.

Calls attention to the opportunities afforded for the determination of the relations of interior and gulf Tertiaries, in the region between and adjacent to the Red and Arkansas rivers. Discusses the correlation of some of the members of the two series.

—— [On the use of the term "Oligocene" in the gulf region.]

International Congress of Geologists, Am. Committee Reports, 1888, F, p. 7, 6 lines.

Am. Geologist, vol. 2, p 273. 1888.

Opinion in regard to its inapplicability.

—— [On the relations of the Grand Gulf series.]

International Congress of Geologists, Am. Committee Reports, 1888, F, pp. 8–9.

Am. Geologist, vol. 2, pp. 274–275. 1888.

To associated and correlated formations.

—— [On the inclusion of "Quaternary" in the Tertiary.]

International Congress of Geologists, Am. Committee Reports, 1888, F, pp. 14–15, ½ p.

Am. Geologist, vol. 2, pp. 280–281. 1888.

Statement of opinion.

—— Agriculture and late Quaternary geology.

Science, vol. 11, pp. 241–242, ½ p. 1888.

Descriptions of evidence of an ancient drainage system in the upper San Joaquin valley, California.

HILL, Frank A. Geology and mining in the northern coal-field of Pennsylvania.

Am. Inst. Mining Engineers, Trans., vol. 15, pp. 699–707. 1887.

General description of the geologic features.

—— Report on the Anthracite region.

Pennsylvania, Report of Geol. Survey, 1886, part 3, pp. 919–1329, 4 plates, 7 sheets in atlas. 1887.

Description of northern and western-middle coal-fields and discussion of structural and stratigraphic relations in some parts of the areas, pp. 925–1007. Sections in northern and eastern and western-middle fields.

—— Lehigh River section continued from Lock 11, southward to the Blue Mountain.

Pennsylvania, Report of Geol. Survey, 1886, part 4, pp. 1372–1385. 1887.

Detailed description of the stratigraphy of beds from Pocono to top of Loraine slate, and of the structural relations of the region. Reference to glacial drift and strim.

HILL, Frank A.—Continued.

—— Report on the metallic paint ores along the Lehigh River.

Pennsylvania, Report of Geol. Survey, 1886, part 4, pp, 1386–1408, sheet 6 in atlas. 1887.

Description of geologic relations, structure of paint beds, and sections in mines.

—— Atlas southern anthracite field, part 2. Pennsylvania Geol. Survey, AA. 13 sheets. Harrisburg. 1889.

Colored geologic maps.

—— Atlas eastern middle anthracite field, part 3. Pennsylvania Geol. Survey, AA. 13 sheets. Harrisburg, 1889.

Colored geologic maps, and columnar and cross sections.

—— Atlas northern anthracite field, part 4. Pennsylvania Geol. Survey, AA. 8 sheets. Harrisburg, 1889.

Colored geologic maps, with marginal columnar sections.

—— Atlas northern anthracite field, part 5. Pennsylvania Geol. Survey, AA. 7 sheets. Harrisburg, 1889.

Cross and columnar sections in coal-measures.

HILL, Robert T. A partial report on the geology of western Texas.

Am. Jour. Sci., 3d series, vol. 33, pp. 73–75. 1887.

Notice of G. G. Shumard's posthumous report. Describes the work of the Shumards, and points out the erroneousness of their opinion in regard to the stratigraphic relations of the subdivisions of the Cretaceous to each other, and to the Tertiary.

—— The topography and geology of the Cross-Timbers and surrounding regions in northern Texas.

Am. Jour. Sci., 3d series, vol. 33, pp. 291–303, plate 6. 1887.

Abstract, Am. Naturalist, vol. 21, p. 172, ½ p. 1887.

Describes the general topographic and geologic features of Texas, and the relations of the Cretaceous. Points out the cause of the cross-timbers, and discusses their extent and geologic relations. Gives a table showing the history, position, equivalency, stratigraphy, paleontology, and occurrence of the subdivisions of the Cretaceous of northern Texas. Accompanied by a hypsometric map.

—— The Texas section of the American Cretaceous.

Am. Jour. Sci., 3d series, vol. 34, pp. 287–309. 1887.

Describes the subdivisions of the Texas

HILL, Robert T.—Continued.

Cretaceous, and discusses their faunal and stratigraphic relations, extent, and equivalency with the Cretaceous of other parts of North America and of Europe. Reviews the literature and paleontology and the equivalency and horizons of the subdivisions of the American Cretaceous.

—— The present condition of knowledge of the geology of Texas.

U. S. Geol. Survey, Bull., vol. 7, pp. 381–473, No. 45. 1887.

Historic sketch of geologic investigation, and summary and review of the results.

—— Notes upon the Texas section of the American Cretaceous. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 36, p. 216, ½ p. 1888.

Refers to relations and equivalency of a new group lying below the Dakota sandstone, and the general relations of the Cretaceous members in Texas.

[——] Notes on the geology of Western Texas.

Geol. and Sci. Bull., vol. 1, No. 6, ½ p., 4°. 1888.

Abstract, Am. Geologist, vol. 3, pp. 51–52, ½ p. 1889.

References to extent and inclination of Carboniferous, divisibility of "red beds" into Permian and Jura Trias, relations of Cretaceous, Quaternary or late Tertiary of plains west of the Sweetwater, evidence of Quaternary lakes in the mountain region west of the Pecos, the terraces of the Rio Grande near El Paso, the lower Cretaceous or possible Jurassic of the southwestern region, and the Quaternary and post-Quaternary history especially of the Llano Estacado region.

—— The Trinity formation of Arkansas, Indian Territory, and Texas.

Science, vol. 11, p. 21, ½ p. 1888.

Describes the characteristics, extent, and general relations of a pre-Cretaceous Mesozoic series to which the term Trinity formation is applied.

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Systematic description of the several formations, discussions of equivalency, geologic history, extent and relations in adjoining and correlated regions, and paleontologic descriptions. Part 2 is an account of economic geology, in which the origin, classification, geologic relations, and improvement of soils are considered.

—— Events in North American Cretaceous history illustrated in the Arkansas-Texas division of the southwestern region of the United States.

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—— [Remarks on occurrence of Macraster Texanus].

Am. Naturalist, vol. 23, p. 168, ½ p. (February No.) 1889.

Reference to its associates and stratigraphic position. Review of Roemer, Neues Jahrbuch, 1888, vol. 1, pp. 191–195, pl.

—— [On the validity of some new species from the Cretaceous of Texas].

Am. Naturalist, vol. 23, p. 109, ½ p. (February No.) 1889.

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—— A portion of the geologic story of the Colorado River of Texas.

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Abstracts, Popular Science Monthly, vol. 36, p. 573, ½ col. 1890. Am. Naturalist, vol. 24, p. 956, ½ p. 1890.

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—— The foraminiferal origin of certain Cretaceous limestones, and the sequence of sediments in North American Cretaceous.

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—— and **PENROSE**, R. A. F., jr. Relation of the uppermost Cretaceous beds of the eastern and southern United States, and the Tertiary-Cretaceous parting of Arkansas and Texas.

Am. Jour. Sci., 3d series, vol. 38, pp. 468–473. 1889. Abstract, Am. Naturalist, vol. 24, p. 769, ½ p. 1800.

Description of the characteristics and relations of the uppermost Cretaceous members in the Texas-Arkansas region, presentation of evidence of their equivalency with the lower marls of the New Jersey region, and an account of the relations and history of the unconformity at the base of the Tertiary. Prefaced by a summary account and table of the Cretaceous members in the Arkansas-Texas region, and concluded by some suggestions in regard to Cretaceous taxonomy.

HILLEBRAND, W. F. Chemistry.

Geology and Mining Industry of Leadville, Colorado, by S. F. Emmons, U. S. Geol. Survey, Mon., vol. 12, pp. 585–608. 1886.

Analyses of eruptives, limestones, ores, vein materials, etc.

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Discussion of the horizon from which the gas is derived.

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—— Circulation of water through the strata of the upper Cretaceous coal measures of Gunnison County, Colorado.

Colorado Sci. Soc., Proc., vol. 2, part 2, pp. 127–133. 1887.

Account of the strata penetrated by boreholes and general sketch of the geology of the region, illustrated by a geologic map.

—— Preliminary notes on the eruptions of the Spanish Peaks region.

Colorado Sci. Soc., Proc., vol. 3, pp. 24–34, pl. 1889.

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—— The recently discovered Tertiary beds of the Huerfano River basin, Colorado.

Colorado Sci. Soc., Proc., vol. 3, pp. 148–164, pl. 1889.

Description of their stratigraphy, structure, distribution, volcanic contents, and relations to the Laramie, and discussion of their history, extent, and taxonomy.

—— Address—The field for original work in the Rocky Mountains.

Colorado Sci. Soc., Proc., vol. 3, pp. 163–184. 1889.

General review of the present condition of knowledge of Colorado geology and summary of discoveries made since the Hayden survey. Refers to occurrence of supposed Cambrian near Ouray, the extent and stratigraphy of the Laramie, and of the Trias in the San Juan region; evidences of glaciation in the White River plateau, the occurrence of supposed Tertiary conglomerate near Ouray and Telluride, the genesis of ores, and the existence of more recent volcanic formations in various parts of the State.

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—— [On the nomenclature of the American lower Paleozoic.]

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Reference to the position of the "Taconic" rocks, the use of the term "Taconic," the use of the smaller American terms like "Niagara," and to a dual nomenclature, paleontologic and stratigraphic.

—— Report of the subcommittee on the Quaternary and Recent.

International Congress of Geologists, Am Committee Reports, 1888, H, pp. 12.

Am. Geologist, vol. 2, pp. 300–306. 1888.

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—— Conglomerates in New England gneisses [a letter addressed to Alexander Winchell.]

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Discusses the age and relations of pebble and fragment-bearing crystalline rocks in Rhode Island, New Hampshire, Vermont, and Massachusetts.

—— Date of the publication of the report upon the geology of Vermont.

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—— On the Archean. See **FRAZER**, Report on Archean.

HOBBS, William H. On the petrographical characters of a dike of diabase in the Boston basin.

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Also describes occurrence, textural relations in its different parts, and some features of the inclosing strata. Analyses.

—— On the rocks occurring in the neighborhood of Ilchester, Howard County, Maryland: Being a detailed study of the area comprised in sheet No. 16 of the Johns Hopkins University map.

Johns Hopkins Univ., Circulars, vol. 7, pp. 69–70, 4°, No. 65. 1888.

Abstract, Am. Naturalist, vol. 22, p. 527, 1888.

Mainly petrographic. References to sequence of the various eruptives and the relations at several localities.

—— On the paragenesis of allanite and epidote as rock-forming minerals.

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Staten Island Nat. Sci. Assoc., Proc., Oct. 8, 1887.

Nine hundred feet in depth in mica schists.

—— [Leaf impressions in Cretaceous (?) sandstone in drift near Arrochar station.]

Staten Island Nat. Sci. Assoc., Proc., Dec. 8, 1888. ¼ col.

Am. Naturalist, vol. 23, p. 459, ¼ p, p. 548, ¼ p. 1889.

Notice of occurrence of drift masses containing fossil leaves, and a fine exposure of modified drift overlain by bowlder drift.

—— [Remarks on fossiliferous sandstones in Cretaceous clays on Staten Island]

Staten Island Nat. Sci. Assoc., Proc., April, 1889, ¼ p.

Am. Naturalist, vol. 23, p. 1036. 1889.

Brief reference to their occurrence on beach at Tottenville and Perth Amboy, and in a new clay outcrop at Prince's Bay.

—— [Triassic shale outcrops on Staten Island.]

HOLLICK, Arthur—Continued.

Staten Island Nat. Sci. Assoc., Proc., April, 1889, ½ p.

Am. Naturalist, vol. 23, pp. 1033–1344, 1037. 1889.

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Nova Scotian Inst., Proc., vol. 7, pp. 7–12. 1888.

References to the bowlders, glacial striæ and drifts, terraces, Silurian, Cambrian, and Triassic outcrops, and occurrences of granites, amygdaloids, and diorites.

—— Notes of examination by Prof. James Hall of the Silurian collection of the Provincial Museum.

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Statement of paleontologic evidence of the equivalency of the subdivisions of the Arisaig group, the beds at Wentworth, and the Silurian beds on Cape Breton.

—— Geology of Halifax and Colchester counties. Part II.

Nova Scotian Inst., Proc., vol. 7, pp. 36–47. 1888.

References to lower Cambrian, lower Carboniferous, granites, evidences of glaciation, contacts of lower Carboniferous and lower Cambrian, and the date of metamorphism of the gold-bearing rocks.

—— Glacial geology of Nova Scotia.

Nova Scotian Inst., Proc., vol. 7, pp. 73–85. 1888.

Description of bowlder deposits at various localities, and discussion of their origin. Reference to striæ, terraces, and glacial history of the region.

—— Nova Scotian superficial geology, with map, systematized and illustrated.

Nova Scotian Inst., Proc., vol. 7, pp. 131–141. 1888.

Reference to the occurrence, relations, and history of the several superficial formations.

—— A geological recreation in Massachusetts centre, U. S. A.

Nova Scotian Inst., Trans., vol. 7, pp. 197–201. 1889.

Includes incidental references to the characteristics of the crystalline rocks of the region, and discusses their age.

HONEYMAN, D.—Continued.

—— Glacial bowlders of our fisheries, and invertebrates, attached and detached.

Nova Scotian Inst., Trans., vol. 7, pp. 205–213. 1889.

Account of bowlders from the fishing banks, and expression of opinion in regard to formation underlying the region.

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Am. Jour. Sci., 3d series, vol. 38, pp. 361–383, pl. IX. 1889.

Descriptions and discussions of contact phenomena, amygdular surfaces, breccias, faults, and flexures, and discussion of their bearing on the origin of the traps.

HOWLEY, James P. The Taconic of eastern Newfoundland.

Am. Geologist, vol. 4, pp. 121–125. 1889.

Statements in regard to the relations of Cambrian and Ordovician members at various localities.

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New York Acad. Sci., Trans., vol. 4, p. 25, ½ p. 1887.

Statement of size and elevation, and suggestion in regard to its origin and history.

HUGHES, N. C. Genesis and geology: the harmony of the scriptural and geological records, pp. 142. 12°. Chocowinity, North Carolina, 1887.

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HUMPHREYS, A. N. Mining methods practiced by the Westmoreland Coal Company, Irwin, Pennsylvania.

Pennsylvania. Geol. Survey., Report for 1886, part 1, pp. 411–456, 7 plates. 1887.

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Geol. Mag., 3d decade, vol. 4, pp. 493–500. 1887.

Abstracts, Eng. and Mining Jour., vol. 44, p. 219. 4°. 1887. Nature, vol. 36, pp. 574–575. 1887. British Assoc. Adv. Science, Report, 1887, pp. 704–705. 1888.

Contains a résumé of the characteristics, equivalency, and distribution of the subdivisions of the Archean, and a brief discussion of the extent of the Taconian in Eastern North America, the equivalency of the Animikie, and the relations of the Keewenawan and Cambrian.

HUNT, T. Sterry—Continued.

—— Gastaldi on Italian geology and the crystalline rocks.

Geol. Magazine., 3d decade, vol. 4, pp. 531–540. 1887.

Abstract, British Assoc. Adv. Science, Report, 1887, pp. 703–704. 1888.

Refers to the unaltered nature of the Montreal granitoid chrysolitic dolerite, and to the magnesian chrysolites in the crystalline limestones of eastern Massachusetts. Briefly discusses the petrography of the Taconian and its separateness from the Huronian and upper Taconic.

—— The genetic history of crystalline rocks.

Canada, Royal Soc., Trans., vol. 4, section III, pp. 7–37. 1887.

An examination of the crenitic "hypothesis in some of its aspects to show how far the conception of a single consolidated igneous mass under the combined action of heat and water may be made to explain satisfactorily the various facts in the history of the Earth's crystalline crust." Discusses the relations of stratified and massive crystalline rocks; foliation; variations and sources of igneous rocks; texture, composition, and minerals of vein stones, and the nature of the crystalline limestones of eastern Massachusetts and New York, and the apatite-bearing veins of Canada.

—— The Taconic question restated.

Am. Naturalist, vol. 21, pp. 114–125, 238–250, 312–320. 1887.

Reviewed by J. D. Dana, Am. Jour. Sci., 3d ser., vol. 33, pp. 412–419. 1887.

Reviews the stages of opinion which have been held in regard to the "Taconic" and related formations. Calls attention to Emmons's modified views in regard to the age of the "upper Taconic." Discusses the history, use, and application of the term "Taconic," the relations of the pre-Potsdam strata in America, and the significance of the discoveries of Dana, Dwight, Ford, Walcott, and others, in the Taconic-Hudson River region, and Rominger and others in the Lake Superior region. Defines the term "Taconian" as applied by him, and considers the use of the word "Cambrian."

—— [On subdivisions, unconformities, characteristics, origin of some members, nomenclature and life of the Archean, origin of serpentine, classification of eruptives, nomenclature of the lower Palæozoic formations.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 68-60, ¾ p.

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Includes a discussion of the subdivision of the pre-Cambrian rocks of North America, and the age, extent, characteristics, and relations of the members of the "Taconian" and Taconic.

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The Taconic at Boston.

Am. Geologist, vol. 2, p. 137, ½ p. 1888.

On the nomenclature proposed by Winchell for the Cambrian rocks.

—— Evolution of the faunas of the lower Lias.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 17–31. 1888.

Includes references to the extent and relations of the basins in which the lower Lias of Europe was deposited, and the equivalency of some of its members.

Idaho, [Caribou Mountain,] VAN DIEST.
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deep well at Nampa, WRIGHT.
geology of, THOMPSON.
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IDDINGS, Joseph P. The nature and origin of lithophysæ, and the lamination of acid lavas.

Am. Jour. Sci, 3d series, vol. 33, pp. 36–45. 1887.

Abstract of a memoir to appear in the Seventh Report of the U. S. Geol. Survey. Describes the micro-structure and lithology of the spherulites and lithophysæ, and the finely laminated structure of the rhyolite of Obsidian Cliff, Yellowstone Park; and discusses the origin of these structural phenomena.

—— On the origin of primary quartz in basalt.

Am. Jour. Sci., vol. 36, pp. 208-221. 1888.

Abstracts, Am. Naturalist, vol. 22, p. 1021, ½ p. 1888. Am. Geologist, vol. 3, p. 52, 7/10 p. 1889.

Petrographic description of quartz-bearing basalts from the Tewan Mountains, Arizona; references to other similar occurrences in California, Colorado, and Nevada, and discussion of the origin of the quartz, and the conditions involved in the solidification of eruptive masses.

—— Obsidian Cliff, Yellowstone National Park.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885–'86, pp. 249–295, pls. 9–18. 1888.

IDDINGS, Joseph P.—Continued.

Abstracts, Am. Geologist, vol. 4, pp. 103–104. 1889. Am. Naturalist, vol. 24, pp 70–71, ½ p. 1890. Am. Jour. Sci., 3d series, vol. 33, pp. 36–45. 1887.

Description of occurrence, lithologic structure, and petrographic characteristics; discussion of the origin, relation, and history of development of the various structures in the obsidian, and references to literature of lithophysæ, and to occurrences of obsidian at other localities.

—— On the crystallization of igneous rocks.

Washington, Phil. Soc., Bull., vol. 11, pp. 65–113. 1889.

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—— Leucite rock, Wyoming. See **HAGUE**, Arnold.

IHLSENG, M. C. Review of the mining interests of the San Juan region.

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Includes description of the geology of the region, and discussion of geologic history, and of the age and origin of the mineral deposits.

—— Report on oil fields of Fremont County.

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—— Notes on Leadville.

Colorado School of Mines, Annual Report, 1887, pp. 29–45.

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driftless area, CHAMBERLIN, T. C. CHAMBERLIN and SALISBURY.

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fossil fuels, COMSTOCK.

fulgerite from Whiteside County, analysis, CLARKE, F. W.

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loess and clays, analyses, RIGGS.

lower Silurian sceptopora, ULRICH.

moraines, CHAMBERLIN, T. C.

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Paleozoic border adjoining Jackson purchase, Kentucky, LOUGHRIDGE.

Peoria County, CHAPMAN.

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types of Devonian system in North America, WILLIAMS, H. S.

Indiana, Benton, Tippecanoe, and Washington counties, GORBY.

Brown County, GORBY and LEE.

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caves and cave life, KINGSLEY.

chipped implement in drift of Jackson County, CRESSON.

Clinton fossils, FOERSTE.

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Indiana, Department of Geology and Natural History, Fifteenth Report, 1886.

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INGALL, E. D. [Preliminary report on mining districts in the Thunder Bay region.]

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Includes a brief description of the characteristics and relations of the Animikie rocks.

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Report on lower Paleozoic, WINCHELL, N. H. BLAKE. DANA. WILLIAMS, G. H. DAWSON, J. W. DUTTON. EMERSON. EMMONS, S. F. FORD. HAGUE. HALL. HITCHCOCK. LE CONTE. MACFARLANE. NEWBERRY. SELWYN. WALCOTT. WINCHELL, A.

Report on upper Paleozoic (Devonic), WILLIAMS, H. S.

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Mesozoic realm, COPE.

Report on Cenozoic (marine), SMITH, E. A. ALDRICH. DALL. HEILPRIN. HILGARD. LE CONTE. NEWBERRY. WHITFIELD, R. P. WINCHELL, A.

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Report on Quaternary and recent, HITCHCOCK.

d'INVILLIERS, E. V. The Pittsburgh coal region.

Pennsylvania, Geol. Survey, Report for 1886, part 1, pp. 1–372, 3 pls., map in pocket, 1887.

Includes descriptions of the structural and stratigraphic relations and a detailed account of the geologic features of the southwestern counties of Pennsylvania. Accompanied by a folded, colored geologic map.

—— Geological map of southwest Pennsylvania, giving the geological outcrops and tidal elevations as a basis for estimating the depths to the oil and gas sands, to illustrate Mr. Carll's report on the oil and gas regions . . . . . scale, 2 miles to 1 inch. June, 1887.

Pennsylvania, Geol. Survey, Annual Report for 1886, part 2, two sheets in pocket. 1887.

The same as the sheet in part 1, with addition of columnar sections and notes by Carll.

—— Report on the iron mines and limestone quarries of the Cumberland-Lebanon valley. 1886.

Pennsylvania, Geol. Survey, Report for 1886, part 4, pp. 1409–1567, maps, sheets 7–11 in atlas. 1887.

Description of structure and stratigraphy of the valley region, the mines, and the quarries of limestone and of Mesozoic sandstone. Brief discussion of the structure in the Dillsburg and Hummelstown regions, and relations of the Newark sandstone.

—— and **McCREATH**, Andrew. The New River-Cripple Creek mineral region of Virginia, pp. 171, 4 plates, and map in pocket. Harrisburg. 1887.

Includes a description of the stratigraphy, distribution, and structure of the several formations in southern Wythe and Pulaski counties, in general and in connection with the ore deposits. Describes the Draper Mountain region in considerable detail, and discusses and figures its complicated structural relations. The report is accompanied by a colored geologic map on which topography and structure are indicated.

d'INVILLIERS and McCREATH—Continued.
—— Comparison of southern cokes and iron ores. See McCreath, A. S. and.
—— Mineral resources of the upper Cumberland valley. See McCreath, A. S. and.

Iowa, Carboniferous echinodermata, KEYES.
chert of upper coal measures in Montgomery County, AM. GEOLOGIST.
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—— On the occurrence of the "forest bed" beneath intra-morainic drift. [Abstract.]

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—— Geological Survey of Kentucky, John R. Proctor, Director. Report on the geology of Lincoln County, 37 pages. Map. [1887?]

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—— Geological Survey of Kentucky, John R. Proctor, Director. Report on the geology of Mercer County, 29 pages. Map. [1887?]

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—— Report on the geology of Nelson County.

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Am. Naturalist, vol. 23, pp. 165–166, ½ p. (February, 1889.)

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Louisiana, iron ores, analyses, RIGGS.

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—— The foot-steps of time in the Red River Valley, with special reference to the salt springs and flowing wells to be found in it.

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Abstract; Ibid., part A, pp. 7–9, Geol. Magazine, 3d decade, vol. 6, pp. 133–134, ½ p. 1889.

Description of Cretaceous, and formations from Carboniferous to Cambrian; flexures and series of overthrust faults. Discussion of some stratigraphic and structural relations. Accompanied by plate of colored sections.

—— Note on the geology of Mount Stephen, British Columbia.

Am. Geologist, vol. 3, pp. 22–25. 1889.

Description of stratigraphy and structure of the Mount Stephen region.

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Am. Inst. Mining Engineers, Trans., vol. 15, pp. 734–753. 1887.

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—— Mineral resources of the upper Cumberland valley of southeastern Kentucky and southwestern Virginia tributary to the proposed Cumberland valley extension of the Louisville and Nashville railroad, 152 pages, map. Louisville, 1888.

Brief prefatory sketch of the general geology and structure, and detailed description of the coal measures.

—— The New River—Cripple Creek mineral region of Virginia. See **D'INVILLIERS, E. V., and.**

McGEE, W J —— Report.

U. S. Geol. Survey, Sixth Report, J. W. Powell, 1884–'85, pp. 25–32. 1885.

Account of geologic cartographic work of the Survey. Notice of studies of the terraces of the central eastern United States, and other investigations.

—— Some features of the recent earthquake.

Sci. Am., Supt., vol. 23, pp. 9205–9206, No. 576. 1887.

From Science, vol. 8, pp. 271–275. 1886.

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Discusses the climatic conditions of the loess period as indicated by its fauna; the relations of the loess to the drift in Iowa and adjacent regions; the early Quaternary submergence of the middle Atlantic slope, and the attendant climatic conditions; the extent of refrigeration in glacial times, and the position of the strata yielding the Ovibos remains at New Madrid and Fort Gibson.

—— The Tuscaloosa formation. Summary of previous observations and opinions.

Tertiary and Cretaceous strata of Tuscaloosa, Tombigbee, and Alabama rivers, by E. A. Smith and L. C. Johnson, U. S. Geol. Survey, Bull., vol. 7, pp. 247–255. No. 43. 1887.

Discussion of age, correlation, and relations of Tuscaloosa and Potomac formations.

—— Résumé.

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References to characteristics, stratigraphy, and relations of the formations and sketch of their history.

—— The geology of the head of Chesapeake Bay.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885–'86, pp. 537–646, pls. 56–71. 1888.

Abstract, Am. Geologist, vol. 4, pp. 113–115. 1889.

Description and analysis of the physiography of the Chesapeake Bay region, and of the coastal plain in general; description of the Columbia and Potomac formations, and their relations in the various exposures, and discussion of their genesis, history, and taxonomy; synopsis of taxonomy of the glacial deposits

McGEE, W J—Continued.

of the middle Atlantic slope; brief references to Archean (?) alluvial, Appomattox, and Sassafras River greensand; discussion of evidence of a displacement bounding the coastal plain on the west, its position, extent, amount, influence on drainage, and topography, date, history, rate, and cause; the genetic relations of topographic forms in general, and the Quaternary history recorded in the Columbia formation; and prognostication in regard to the occurrence of artesian waters in the region. Accompanied by a stereogram of the middle Atlantic slope.

—— Report —— Potomac Division of Geology.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885–'86, pp. 104–111. 1888.

Includes a reference to the equivalency and history of the Potomac and Tuscaloosa formations.

—— Three formations of the Middle Atlantic Slope.

Am. Jour. Sci., 3d series, vol. 35, pp. 120–143, 328–330, 367–388, 448–466, pls. II, VI, VII. 1888.

Abstract. Nature, vol. 38, p. 91, 15 lines, p. 190, 11 lines. 1888. Am. Geologist, vol. 2, pp. 129–131. 1888.

Description of character, distribution, and relations of the Potomac and Columbia formations, and of a new later Tertiary formation, designated the "Appomattox," from North Carolina to New Jersey. Discussion of stratigraphic relations, origin of materials, conditions of deposition, taxonomy, and bearing on geologic history, especially on the Quaternary. Synopsis of literature of the Columbia formation and of the glacial history of the United States. Accompanied by a stereogram of the middle Atlantic slope.

—— The classification of geographic forms by genesis.

National Geogr. Mag., vol. 1, pp. 27–36. 1888.

Definition and classification of geologic phenomena and discussion of their relation to the genesis of geographic features.

—— The Columbia formation.

Am. Assoc. Adv. Science, Proc., vol. 36, pp. 221–222. 1888.

General notice. Discussion of origin and mode of deposition of its materials and climatic conditions indicated by its stratigraphy and relations.

—— Paleolithic man in America: his antiquity and environment.

Popular Science Monthly, vol. 34, pp. 20–36. 1888.

Includes a sketch of the glacial history of North America, especially of the lower Delaware Valley and the relations of the Trenton gravels.

McGEE, W J—Continued.

—— [On some peculiarities of the superficial deposits of northeastern Iowa.]

Am. Geologist, vol. 2, pp. 137–138, ½ p. 1888.

Brief reference to forest bed intercalated between the drifts, the occurrence of kames and asar, the distribution of the loess, and certain anomalous relations of the drainage.

—— Notes on the geology of Macon County, Missouri.

St. Louis, Acad. Sci., Trans., vol. 5, pp. 305–336. 1888.

Description of topography, the alluvial, aquo-glacial and glacial deposits, the Carboniferous rocks and coals, and structure. Discussion of classification of plains, sketch of Pleistocene history, and correlation of coal-beds and of the strata pierced by drill-holes.

—— Topographic types of northeastern Iowa.

Am. Naturalist, vol. 23, p. 808, ½ p. 1889.

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—— Geological antecedents of man in the Potomac valley.

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—— Restoration of Brontops robustus, from the Miocene of America.

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Am. Geologist, vol. 1, pp. 100–110, 179–190, 305–315; vol. 2, pp. 39–44 (to be continued). 1888.
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—— On Sceptropora, a new genus of Bryozoa, with remarks on Helipora Hall, and other genera of that type.
Am. Geologist, vol. 1, pp. 228–234. 1888.
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Form and position of sea level, WOODWARD.
Subaerial decay of rocks, RUSSELL, I. C.
Geology of Nantucket, SHALER.

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Synopsis of flora of Laramie, WARD.
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Fossil fishes and fossil plants of the Triassic rocks of New Jersey and the Connecticut valley, NEWBERRY.

United States National Museum, Proceedings, vol. 11.

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Peridotite from Little Deer Island, Maine, MERRILL.

Measuring thickness of inclined strata, WALCOTT.

United States, Report: The iron regions of northern Louisiana and eastern Texas, JOHNSON.

UPHAM, Warren. The upper beaches and deltas of the glacial Lake Agassiz.

U. S. Geol. Survey, Bull., vol. 6, pp. 389–470, plate. No. 39. 1887.

Abstracts, Science, vol. 10, pp. 103–104, 1887; Am. Geologist, vol. 1, pp. 64–65, ½ p., 1888; Popular Science Monthly, vol. 32, p. 420, ½ col., 1888.

Introductory sketch of the lake, its beaches, bed, outlet, northern barrier, and depth, and a discussion of the cause and significance of the slope of its shore lines. Describes in detail the beaches and their relations to the drifts, drainage, and topography. Incidentally remarks on some features of the drift and on the geology of Pembina Mountain and vicinity.

—— Prof. Henry Carvill Lewis and his work in glacial geology.

Am. Geologist, vol. 2, pp. 371–379. 1888.

References to results of his studies of the terminal moraine in eastern United States and drifts of Great Britain. List of papers.

—— The recession of the ice sheet in Minnesota in its relation to the gravel deposits overlying the quartz implements found by Miss Babbitt at Little Falls, Minnesota.

Boston Soc. Nat. Hist., Proc., vol. 23, pp. 436–447. 1888.

Description of the relations of the containing gravels and a sketch of the history of the ice-sheet recession in the Minnesota region.

UPHAM, Warren—Continued.

—— The geology of Carver and Scott counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 102–147, map. 1888.

Description of Cambrian and Cretaceous areas and the drifts. Artesian well records; terraces. Discussion of the relations and origin of some of the drifts, and the history of some ancient drainage features. Accompanied by a colored geologic map.

—— The geology of Sibley and Nicollet counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 148–179, map. 1888.

Descriptions of drifts, terraces and outcrops of Archean, Cambrian, and Cretaceous. Discussion of equivalency of some of the Cambrian members and the relation and origin of some of the drifts. Accompanied by a colored geologic map.

—— The geology of McLeod County.

Minnesota, Geology of, Final Report, vol. 2, pp. 180–189. Map. 1888.

Description of the drifts, and discussion of the relations and origin of some of their features. Accompanied by a colored geologic map.

—— The geology of Renville County.

Minnesota, Geology of, Final Report, vol. 2, pp. 190–204. Map. 1888.

Description of drifts, Archean, Cretaceous, terraces, and interglacial forest bed. Accompanied by a colored geologic map.

—— The geology of Swift and Chippewa counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 205–219. Map. 1888.

Description of drifts, Archean outcrops, buried moraine, preglacial drainage channels, and terraces. Accompanied by a colored geologic map.

—— The geology of Kandiyohi and Meeker counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 220–242. Map. 1888.

Description of drifts, and sketches of glacial history. Accompanied by a colored geologic map.

—— The geology of Wright County.

Minnesota, Geology of, Final Report, vol. 2, pp. 243–263. Map. 1888.

Description of drifts and doubtful Cretaceous outcrops. Discussions of the relations of some of the drifts, and some features of glacial history. Accompanied by a colored geologic map.

—— The geology of Chisago, Isanti, and Anoka counties.

UPHAM, Warren—Continued.

Minnesota, Geology of, Final Report, vol. 2, pp. 399–425. Map. 1888.

Description of drifts, terraces, and of outcrops of traps, St. Croix sandstone, lower magnesian limestone, and Trenton limestone. Discussion of the relations and origin of some of the drifts. Accompanied by a colored geologic map.

—— The geology of Benton and Sherburne counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 426–444. Map. 1888.

Description of Archean areas, trap dikes, and drifts. Discusses relations of some of the drifts. Accompanied by a colored geologic map.

—— The geology of Stearns County.

Minnesota, Geology of, Final Report, vol. 2, pp. 445–470. Map. 1888.

Description of drifts, Archean and Cretaceous, and sketch of glacial history. Accompanied by a colored geologic map.

—— The geology of Douglas and Pope counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 471–498. Map. 1888.

Description of drifts. References to glacial history indicated by some of the features, relations of the drifts, and preglacial topographic features; presence of Cretaceous. Accompanied by a colored geologic map.

—— The geology of Grant and Stevens counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 499–510. Map. 1888.

Description of drifts and beaches of glacial Lake Agassiz. Accompanied by a colored geologic map.

—— The geology of Wilkins and Traverse counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 511–533. Map. 1888.

Description of shore phenomena, and sketch of history of glacial Lake Agassiz. Reference to underlying Cretaceous found in well at Fargo. Accompanied by a colored geologic map.

—— The geology of Ottertail County.

Minnesota, Geology of, Final Report, vol. 2, pp. 534–561. Map. 1888.

Description of drifts and beaches of Lake Agassiz. Discussion of nature of underlying rocks, and the origins of some of the drift deposits. Accompanied by a colored geologic map.

—— The geology of Wadena and Todd counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 562–579. Map. 1888.

UPHAM, Warren—Continued.

Description of drifts, Archean, and diorite. Discussion of the nature and sequence of some of the glacial phenomena. Accompanied by a colored geologic map.

—— The geology of Crow Wing and Morrison counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 580–611. Map. 1888.

Description of drifts, Archean, staurolitic and mica schists, and Cretaceous. Discusses origin of some of the drift materials. Some copies accompanied by a colored geologic map.

—— The geology of Mille Lacs and Kanabec counties.

Minnesota, Geology of, Final Report, vol. 2, pp. 612–628. Map. 1888.

Description of drifts, and Archean and Potsdam outcrops. Accompanied by a colored geologic map.

—— The geology of Pine County.

Minnesota, Geology of, Final Report, vol. 2, pp. 629–645. Map. 1888.

Description of drifts, Archean, Keweenawan, and Cambrian outcrops, and ancient outlet of Lake Superior. Accompanied by a colored geologic map.

—— The geology of Becker County.

Minnesota, Geology of, Final Report, vol. 2, pp. 646–655. Map. 1888.

Description of drifts, and discussion of extent and relation of underlying rocks. Accompanied by colored geologic map.

—— The geology of Clay County.

Minnesota, Geology of, Final Report, vol. 2, pp. 656–671. Map. 1888.

Description of drifts and shore phenomena of glacial Lake Agassiz. References to preglacial topography, and well at Fargo into supposed Cretaceous strata. Accompanied by a colored geologic map.

—— Glaciation of mountains in New England and New York.

Am. Geologist, vol. 4, pp. 165–174, 205–216. 1889.

Appalachia, vol. 5, pp. 291–312. 1889.

Discusses the extent, thickness, direction of movement, and action on elevated regions of the great ice caps of the glacial period.

—— Ascents of Camel's Hump and Lincoln Mountain, Vermont.

Appalachia, vol. 5, pp. 319–326. 1889.

Includes some brief references to the characteristics of the rocks, evidences of glaciation, and glacial drifts.

—— Marine shells and fragments of shells in the till near Boston.

UPHAM, Warren—Continued.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 127–141. 1889.

Am. Jour. Sci., vol. 37, pp. 359–372. 1889.

Abstract, Nature, vol. 40, p. 68, 11 lines. 1889; Am. Geologist, vol. 3, p. 399, ½ p. 1889.

Summary account of the various localities; description of deposits in which the shells occur, discussion of their transportation, and their bearing on the recency of the glacial period, late preglacial climatic conditions and height of sea level, and a general review of the evidence bearing on the cause, nature, and amounts of post-glacial submergence in eastern North America.

—— [Age and origin of the pot-holes at Colrasset.]

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 226–228. 1889.

Includes reference to some other pot-holes of supposed glacial origin.

—— The structure of drumlins.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 228–242. 1889.

Abstract, Am. Geologist, vol. 5, p. 61, ½ p.

Detailed description of several drumlins in eastern Massachusetts, and discussion of their relations and history.

—— The glacial moraines of Minnesota.

Minnesota Acad. Sci., Bull., vol 3, part 1, p. 12, ½ p. 1889.

Short notice of paper. Classified list of moraines, and statement in regard to their lateral nature.

—— Changes in the currents of the ice of the last glacial epoch in eastern Minnesota.

Minnesota Acad. Sci., Bull., vol. 3, part 1, pp. 51–56. 1889.

Discussion of the history and results of the glacial flows, and of evidence of the existence of certain glacial rivers in the region.

—— Description of maps showing the climate, geography, and geology of Minnesota.

Minnesota Acad. Sci., Bull., vol. 3, part 1. pp. 151–155. 1889.

Includes a general account of the characteristics and distribution of formations in Minnesota.

—— [Beaches of Lake Agassiz.] See **CHAMBERLIN**, Division of glacial geology.

Utah, Cambrian, MATTHEW. WALCOTT.
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gilsonite, Uinta County, RAYMOND.
gold and silver mining, HOLLISTER.
Henry Mountain laccolites, CROSS. EMMONS, S. F.
iron ore of southern Utah, BLAKE.
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marbles, NEWBERRY.
mountain upthrusts, Uinta, etc., WHITE, C. A.
obsidian, IDDINGS.
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Permian of Texas, HILL, R. T.
relations of Laramie, WHITE, C. A.
stratigraphic position of Olenellus, WALCOTT.
structural relations of ore deposits, EMMONS, S. F.
sulphur deposits, FAUR.
upper Eocene formation, SCOTT.

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VAN DIEST, P. H. Notes on some Boulder County veins.

Colorado Sci. Soc., Proc., vol. 2, part 2, pp. 50–55, plate. 1887.

Describes the gneisses, granites, felsite dikes, and their contained minerals. On accompanying map indicates boundary of metamorphic and sedimentary rocks.

—— Address of the retiring president.

Colorado Sci. Soc., Proc., vol. 2, pp. 278–285. 1888.

Refers to geologic features of Caribou Mountains, and at the Wilson mine, Idaho, in connection with the occurrence of gold at these localities.

—— Colorado volcanic craters.

Colorado Sci. Soc., Proc., vol. 3, pp. 19–24. 1889.

VAN DIEST, P. H.—Continued.

Describes some features of craters and lava flows in Rio Grande County, and refers to reports of craters at other points in Colorado.

VAN HISE, C. R. Notes on the enlargement of hornblendes and augites in fragmental and eruptive rocks.

Am. Jour. Sci., 3d series, vol. 33, pp. 385–388. 1887.

Abstract, Am. Naturalist, vol. 22, p. 168, ½ p. 1888.

Calls attention to Becke's discovery of the fact in 1883, and describes some Penokee-Gogebic altered diabases exhibiting secondary hornblendic enlargements on augite grains.

—— The iron ores of the Penokee-Gogebic series of Michigan and Wisconsin.

VAN HISE, C. R.—Continued.

Am. Jour. Sci., 3d series, vol. 37, pp. 32–48, pl. 2. 1889.

Abstracts, Nature, vol. 39, p. 310, 8 lines, 1889; Am. Geologist, vol. 3, pp. 197–198, 1889.

Brief account of geology of Penokee-Gogebic region, description of relations of ore deposits and associated intrusive rocks, and discussion of the genesis of the ores.

—— The chemical origin of the Vermilion Lake iron ores.

Am. Geologist, vol. 4, pp. 382–383. 1889.

Review of N. H. and H. V. Winchell "On a possible chemical origin of the iron ores of the Keewatin in Minnesota." Incidentally discusses the history of the discovery of unconformity at the base of the Keewatin series, and the correlation of some of the formations which are included in the Keewatin series.

VAN NESS, W. W. J. Tin in North Carolina.

Eng. and Mining Jour., vol. 44, p. 344, ½ p. 1887.

General description of geology of King's Mountain region.

Vassar Brothers' Institute, Transactions, vol. 4.

Cutting at Croton Point, New York, WARRING.

Evolution of continents, WARRING.

Plication in continental elevation, DWIGHT.

Primordial of Wappinger Valley limestone region, DWIGHT.

Vermont, great primordial quartzite, WINCHELL, N. H.

Camel's Hump and Mount Lincoln, UPHAM.

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Taconic of Georgia, and Report on Geology of Vermont, MARCOU.

Taconic question restated, HUNT.

Taconic system of Emmons, MILLER, WALCOTT.

new locality of camptonite, NASON.

Virginia, age of Potomac formation, WARD.

antecedents of man in the Potomac valley, MCGEE.

Virginia—Continued.

coal, ASHBURNER.

coal-field of southwestern Virginia, KILLEBREW.

Columbia formation, MCGEE.

faults of southwestern Virginia, STEVENSON.

flora of older Mesozoic, STUR.

gas and coal, Chesterfield County, RUSSELL, I. C.

Glenmore iron estate, Greenbrier County, PAGE.

iron ore, Rockbridge County.

lower Carboniferous, STEVENSON.

Low Moor iron ore, LYMAN.

mineral resources of southwestern Virginia, PROCTOR.

Natural Bridge, Balcony Falls, Luray, Great Valley, BRITTON.

natural coke from Midlothian, analysis, RIGGS.

New River-Cripple Creek region, D'INVILLIERS and MCCREATH.

Oriskany bowlder near Washington, District of Columbia, CURTICE.

reconnaissance in southwestern Virginia, STEVENSON.

Richmond coal-field, CLIFFORD. NEWELL.

surface geology of southwestern Virginia, STEVENSON.

sauropoda from the Potomac formation, MARSH.

terraces, MCGEE. STEVENSON. WHITE, I. C.

three formations of the middle Atlantic coast, MCGEE.

Trenton limestone from Lexington; analysis, RIGGS.

upper Cumberland valley, MCCREATH and D'INVILLIERS.

[younger Mesozoic from Richmond southward], WARD.

VOGDES, Anthony W. Some forgotten Taconic literature.

Am. Geologist, vol. 2, pp. 352–355. 1888.

Descriptive notes and abstracts of papers by Dewey in 1819 and 1824, and Emmons, 1842 and 1846.

—— The genera and species of North American Carboniferous trilobites.

New York Acad. Sci., Annals, vol. 4, pp. 69–105, pls. II, III. 1888.

Includes a general sketch of the distribution of the Carboniferous members in the United States, pp. 70–74.

W.

WADSWORTH, M. E. Preliminary description of the peridotytes, gabbros, diabases, and andesytes of Minnesota.

Geol. and Nat. Hist. Survey of Minnesota, Bull. No. 2, pp. 9–159, 12 plates. 8°. St. Paul, 1887.

Abstract, Am. Naturalist, vol. 22, pp. 452–453, ¾ p. 1888.

Description and discussion of the micro-petrography of a large collection in greater part from the northeastern part of the State. Colored plates of micro rock sections.

Also includes a discussion of classification, history, and relations of basic crystalline rocks.

—— The Keweenawan system.

Science, vol. 10, p. 166, ½ p. 1887.

Describes a locality on the Hungarian River; a graduation of the eastern sandstone into the Keweenaw rocks is exhibited without intervening fault. Discusses the copper-bearing rocks and relative position of the sandstones.

—— [On subdivisions, unconformities, characteristics, origin of some members, nomenclature, and life of the Archean, and origin of serpentine.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 69–70.

Wagner Free Institute, Transactions, vol. 1.

Explorations on west coast of Florida, etc., HEILPRIN.

WALCOTT, Charles D. Report * * * Division of Paleozoic Invertebrates.

U. S. Geol. Survey, Sixth Annual Report, 1884–'85, pp. 74–78. 1885.

Notice of Paleozoic rocks of central Texas and Devonian fossils from northern Montana.

—— The Taconic system.

Am. Jour. Sci., 3d series, vol. 33, pp. 153–154. 1887.

Announces results of recent field work in Taconic region which indicates: 1. That the granular quartz is the shore deposit of the shales, sandstones, and limestones of the "upper Taconic and is Middle Cambrian in age," and 2. That the Potsdam is represented by the base of the limestone on the eastern side and by hydromica shales on the west side of the range; the limestones and overlying slates of the Taconic range representing the calciferous and Hudson River groups, as shown by Dana.

—— Fauna of the "upper Taconic" of Emmons, in Washington County, New York.

WALCOTT, Charles D.—Continued.

Am. Jour. Sci., 3d series, vol. 34, pp. 187–199, plate 1. 1887.

Statement of stratigraphic position and account of mode of occurrence.

—— Section of lower Silurian (Ordovician) and Cambrian strata in central New York, as shown by a deep well near Utica. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 36, pp. 211–212, ½ p. 1888.

Description of drill-hole 2,250 feet in depth.

—— Discovery of fossils in the lower Taconic of Emmons. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 36, pp. 212–213. 1888.

Describes occurrences of middle Cambrian species in the quartzites and Trenton-Chazy species in the limestones of southwestern Vermont, and calls attention to their bearing on the question of the age of the Taconic system.

—— The Taconic system of Emmons, and the use of the name Taconic in geologic nomenclature.

Am. Jour. Sci., 3d series, vol. 35, pp. 229–242, pl. III, pp. 307–327, 394–401. 1888.

Abstract, Nature, vol. 37, p. 500, 14 lines; p. 623, 11 lines. 1888.

Review by Jules Marcou, Am. Geologist, vol. 2, pp. 10–23, 67–88. 1888.

Review of Emmons and others, description and discussion of relations in the Taconic region, announcement of discovery of fossils and structural features throwing new light on the relative position, equivalency, and relations of the various members of the Taconic system, discussion of nomenclature and classification of the Cambrian formations. Accompanied by a colored geologic map.

—— Cambrian fossils from Mount Stephen, Northwest Territory of Canada.

Am. Jour. Sci., 3d series, vol. 36, pp. 161–166, September number. 1888.

Read to Biological Society of Washington, 1888.

Review of some of the species described by Rominger, and discussion of the paleontologic evidence on the stratigraphic position of the Cambrian of Mount Stephen.

—— [On the nomenclature and origin of the Archean and the use of the term Taconic.]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 57–58.

—— Synopsis of conclusions on the "Taconic system" of Emmons.

WALCOTT, Charles D.—Continued.

International Congress of Geologists, Am. Committee Reports, 1888, B, pp. 25–29.

Am. Geologist, vol. 2, pp. 215–219. 1888.

Extracts from paper in American Journal of Science, 1888, with additional notes.

—— Report—Paleozoic division of invertebrate paleontology.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 113–117. 1888.

Reference to the formations constituting the Paleozic in central Nevada, especially to the discovery of Devonian and lower Carboniferous; the thickness and horizon of the Wahsatch Cambrian; to studies by H. S. Williams on the stratigraphy and faunal relations of the Devonian of southern New York; and collection of Cambrian fossils in the southern Appalachian by Cooper Curtice.

—— Stratigraphic position of the Olenellus faunæ of North America and Europe.

Am. Jour. Sci., 3d series, vol. 37, pp. 374–392, vol. 38, pp. 29–42. 1889.

Abstracts, Nature, vol. 40, pp. 68, 310–311, 24 lines, 1889. New York Acad. Sci., Trans., vol. 8, p. 176, ½ p. 1889.

Review and discussion of paleontologic and stratigraphic relations of the lower Cambrian to the middle Cambrian, and of the stratigraphic position, geographic distribution, zoology and stratigraphic characteristics of the Olenellus zone in America and Europe. Includes a description of the Cambrian of Newfoundland based on recent examinations, and a general review and tabulation of Cambrian taxonomy.

—— A simple method of measuring the thickness of inclined strata.

U. S. National Museum, Proc., vol. 11, pp. 447–448. 1889.

WALKER, J. B. Notes on the geology of Burnet County.

Geol. and Sci., Bull., vol. 1, February, 1889. 4°.

Statements in regard to characteristics, relations, and distribution of the Cretaceous and Carboniferous.

WARD, Lester F. Synopsis of the flora of the Laramie group.

U. S. Geol. Survey, Sixth Report, J. W. Powell, 1884-'85, pp. 399–557, pls. III–LXV. 1885.

Abstracts, Am. Naturalist, vol. 21, pp. 1011–1012; Am. Geologist, vol. 2, pp. 56–58, 1888.

Review, Science, vol. 10, pp. 150–151. 1887.

Reviews the opinions which have been held in regard to the age and position of the Laramie and equivalent formations. Describes the nature, extent, and vegetation of the group and discusses its age, history, distribution, and floral relations, the equivalency of groups near its horizon, and the stratigraphic and geographic range of the flora of the Laramie, Senonian, and Eocene. Gives a brief account of observation on the lower Tertiary or upper Cretaceous at several points in Colorado and Wyoming, and along the Missouri from Fort Benton to Bismarck.

WARD, Lester F.—Continued.

—— Evidence of the fossil plants as to the age of the Potomac formation.

Am. Jour. Sci., 3d series, vol. 36, pp. 119–131. 1888.

Abstract, Nature, vol. 38, p. 462, 9 lines. 1888. Read to National Academy of Sciences, 1888.

—— Report—Division of paleobotany.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 123–126. 1888.

Includes a brief reference to the occurrence of outcrops of younger Mesozoic from Richmond southward, and at Weldon, North Carolina.

WARDROPER, D. Lee. The formation of coal beds.

Eng. and Mining Jour., vol. 45, p. 473, ½ col., 4°. 1888.

Describes occurrence of small lenticular coal masses in sandstone over coal beds in northwestern Georgia.

WARRING, Charles B. The cutting at Croton Point, New York.

Vassar Brothers' Inst., Trans., vol. 4, pp. 274–278. 1887.

Describes and figures beds of sand and cobbles unconformably overlain by two layers of very fine material conformable to the surface of the ground, on Hudson River just north of the mouth of the Croton River.

—— The evolution of continents.

Vassar Brothers' Inst., Trans., vol. 4, pp. 256–271, 273–274. 1887.

General discussion of the relations of continental masses; the theories of continental formation and the solidification of the earth's crust. Advances the hypothesis that the continents originally constituted a great triangular clot of solidified matter floating on a molten surface, and by breaking apart near the central line at the present Atlantic Ocean, separated into continents which were thence solidified into their present positions.

Washburn College Laboratory, Bulletin, vol. 2.

Paleontology of the Plains, CRAGIN.

Region south of great bend of the Arkansas, CRAGIN.

Washington, analysis of soil, SCHNEIDER.

Washington—Continued.
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invertebrate fossils from Pacific coast, WHITE, C. A.
Mount Ranier and the glaciers, WILLIS.
Puget group, WHITE, C. A.
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Washington, Philosophical Society, Bulletin, vol. 9.
Faults of Great Basin, etc., RUSSELL.
Geologic history of Sierra Nevada, GILBERT.
Geology of northern California, DILLER.
Sierra structure not extended into Washington, WILLIS.

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Mount Ranier and its glaciers, WILLIS.

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Problems of physical geology, DUTTON.
Crystallization of igneous rocks, IDDINGS.

WASMUTH, Henry A. Studies on the stratification of the anthracite measures of Pennsylvania.

Franklin Inst. Jour., vol. 124, pp. 109–126, 4 plates. 1887.
Abstract, Am. Naturalist, vol. 24, p. 768, ½ p. 1890.
Discusses relations of flexures to faults and the occurrence and causes of offsets in some of the collieries of the anthracite region.

—— Notes on the Pittsburg coal bed and and its disturbances.

Am. Geologist, vol. 1, pp. 272–277. 1888.
Description and discussion of flexures and faults at Biddle, Westmoreland County, Pennsylvania.

—— Notes on the structural geology of the Carboniferous formation of Pennsylvania.

Am. Geologist, vol. 2, pp. 311–323. 1888.
Discussion of the structural relations of the coal beds in the Pittsburg and in the anthracite regions.

—— The southern anthracite coal field of Pennsylvania—its enormous disturbances and consequent premature exhaustion.

Franklin Inst. Jour., vol. 125, pp. 110–114. 1888.
Reference to faults and steep folds indicating the existence of much greater disturbance than is shown on the geological survey maps.

WEBER, Adolph H. Natural gas.

California, Seventh Report of State Mineralogist, pp. 181–191. 1888.
Section in superficial deposits at Eureka; notice of occurrences of lignite at various points in Humboldt, Trinty, Tehama, Mendocino, Sonoma, Colusa, and Shasta counties.

—— Petroleum and asphaltum in northern California.

California, Seventh Report of State Mineralogist, pp. 195–202. 1888.
Gives sections on coast south of Bear River and at Point Arena showing relations of bituminous beds.

WEBSTER, Clement L. On the glacial flow in Iowa.

Am. Naturalist, vol. 21, pp. 758–761. 1887.
Discusses the evidence of three ice flows. Describes striæ, the drift, and the inner and outer moraines of the last two glacial advances.

—— Notes on the geology of Johnson County, Iowa.

Am. Naturalist, vol. 22, pp. 408–419, pl. 5. 1888.
Description of pot-holes and old river channel in Devonian limestone at its overlap by the Carboniferous; peat beds under the drift at various points in Iowa; terraces along Iowa River; loess and drift. Brief discussion of age, origin, and conditions of deposition of the loess.

—— Notes on the Rockford shales.

Am. Naturalist, vol. 22, pp. 444–446. 1888.
Reference to lithologic and paleontologic variations at different localities, and description of fossils from Owens's Grove, Cerro Gordo County.

—— On the glacial drift and loess of a portion of the northern-central basin of Iowa.

Am. Naturalist, vol. 22, pp. 972–979. 1888.
Drifts, loess, vegetal beds between drift sheets, distribution of erratics, terraces, relation of drainage to structure.

—— Description of new species of fossils from the Rockford shales of Iowa.

Am. Naturalist, vol. 22, pp. 1013–1018. 1888.
Reference to the great variety of conditions of deposition indicated in the Devonian of

WEBSTER, Clement L.—Continued.

Iowa, and the effects upon the faunal relations.

—— A general preliminary description of the Devonian rocks of Iowa, which constitute a typical section of the Devonian formation of the interior continental area of North America.

Am. Naturalist, vol. 23, pp. 229–243. 1889.

Description of the characteristics, distribution, and relations, and discussion of equivalency, stratigraphic range, and paleontologic relations of the several members.

—— A description of the Rockford shales of Iowa.

Davenport, Acad. Sci., Proc., vol. 5, part 1, pp. 100–109. 1889.

Description of stratigraphy, and lists of fossils.

WEED, Walter Harvey. On the formation of siliceous sinter by the vegetation of thermal springs.

Am. Jour. Sci., 3d series, vol. 37, pp. 351–359. 1889.

Describes the formation of siliceous deposits by algæ and mosses in the geyser waters in the Yellowstone Park; discusses their rate of growth; gives analyses of Yellowstone Park and New Zealand sinters, and discusses the nature of the latter. Preceded by a general discussion of the deposition of silica by geyser waters.

WENDT, Arthur F. The copper ores of the southwest.

Am. Inst. Mining Engineers, Trans., vol. 15, pp. 25–77, plate. 1887.

Abstract, Eng. and Mining Jour., vol. 43, pp, 94–96, 112–114, 133–134, 150–152, 183–185. 1887.

Describes the occurrence of ores in Carboniferous limestones, and associated eruptives at Santa Rita, New Mexico, Clifton, Bisbee, and Black Range districts, Arizona, and in recent formations at Moleje, Lower California. Includes notes on micropetrography, by A. A. Julien.

West Virginia, coal, ASHBURNER.

coal from Jefferson County; analysis, WHITFIELD, J. E.

WHITE, Charles A. Report . . . . . Division of Mesozoic Invertebrates.

U. S. Geol. Survey, 6th Annual Report, J. W. Powell, 1884–'85, pp. 72–74. 1885.

Announces his conclusions in regard to the position of the Chico and Téjon groups, and the auriferous slate series of California Calls attention to the occurrence of a Cretaceous formation in Mendocino County, California, to which the provisional name of Wallala group is given.

WHITE, Charles A.—Continued.

—— On the age of the coal found in the region traversed by the Rio Grande.

Am. Jour. Sci., 3d series, vol. 33, pp. 18–20. 1887.

Refers it either to the Laramie or Fox Hills formation, or to both, and describes the extension of these formations southward into Mexico.

—— On the inter-relation of contemporaneous fossil faunas and floras.

Am. Jour. Sci., 3d series, vol. 33, pp. 364–374. 1887.

Discusses the faunal and floral relations and contemporaneity of deposition of the Laramie, and the equivalents of the Bridger, and the stratigraphic position of these groups.

—— On the relation of the Laramie molluscan fauna to that of the succeeding fresh-water Eocene and other groups.

U. S. Geol. Survey, Bull., vol. 5, pp. 391–442, 5 plates. No. 34. 1887.

Abstracts, Science, vol. 10, pp. 126–127. 1888; Popular Science Monthly, vol. 33, p. 420, ½ col. 1888.

Describes Wasatch fossils from San Pete Valley and adjacent portions of Wasatch Mountains, and discusses the faunal and stratigraphic relations of these beds, and of the Bear River Laramie, Wasatch, Laramie, Puerco, and Fort Union groups. (The abstract in Science is a very complete one.)

—— On the Cretaceous formations of Texas, and their relation to those of other portions of North America.

Philadelphia, Acad. Sci., Proc., 1887, part 1, pp. 39–47.

Describes results of studies by R. T. Hill, from which is given a descriptive table of the strata of the eastern half of Texas, and their supposed equivalents in the Mississippi and upper Missouri River sections. Discusses the equivalency, distribution, subdivisions, and relations to associated formations.

—— On the occurrence of later Cretaceous deposits in Iowa.

Am. Geologist, vol. 1, pp. 221–227. 1888.

References to localities and occurrence of fossils, and discussion of their stratigraphic position in the Cretaceous, the position of Cretaceous shore line, and original thickness and extent of the Cretaceous in Iowa.

—— On the relation of the Laramie group to earlier and later formations.

Am. Jour. Sci., 3d series, vol. 35, pp. 432–438. 1888.

Abstract, Nature, vol. 38, p. 189, 7 lines. 1888.

Description of the relations of the Laramie in the lower Rio Grande region in Texas and

WHITE, Charles A.—Continued.

Mexico, references to the relations of the Belly River series, and discussion of the history of the late Cretaceous and early Tertiary in western America, and the Cretaceous age of the greater part of the Laramie.

—— On the Puget group of Washington Territory.

Am. Jour. Sci., 3d series, vol. 36, pp. 443–450. 1888.

Abstract, Nature, vol. 39, p. 189, 16 lines. 1888.

Statement of general relations and discussion of genesis, history, biologic relations, and correlation with Laramie and Chico-Téjon groups.

—— Mountain upthrusts.

Am. Naturalist, vol. 22, pp. 399–408. 1888.

Sections and descriptions of the Uinta fold, and the Junction and Yampa mountain upthrusts, and discussion of their history and the philosophy of their uplift.

—— [On the fauna of the Permian of Baylor, Archer and Wichita counties, Texas.]

Am. Naturalist, vol. 22, p. 926, ¼ p. 1888.

Statement of his opinion in regard to the Permian age of the formations.

—— On Hindeastræa, a new generic form of Cretaceous Astræidæ.

Geol. Magazine, 3d decade, vol. 5, pp. 362–364. 1888.

Incidentally refers to stratigraphic position of Ripley group.

—— Remarks on the genus Aucella, with special reference to its occurrence in California.

U. S. Geol. Survey, Monograph, No. 13, Quicksilver deposits of the Pacific slope. By G. F. Becker, pp. 226–232, plates III, IV. 1888.

Includes a statement in regard to the age of the containing series indicated by its occurrence.

—— Report—Mesozoic division of invertebrate paleontology.

U. S. Geol. Survey, Seventh Report, J. W. Powell, 1885-'86, pp. 117–120. 1888.

References to thickness, age, and fauna of coal-bearing series in hills south of San Pete valley, Utah, their faunal relation to the Laramie and their equivalency with the coal-bearing beds near Evanston, Wyoming; the occurrence of coal in the Laramie in Cottonwood Cañon, the equivalency of the coal series in Pleasant valley and Coalville, Utah, and the marine origin of the containing strata; the faunal relations of the Laramie and Wasatch, and extent of land area during the latter part of the Jurassic period.

WHITE, Charles A.—Continued.

—— The lower Cretaceous of the Southwest and its relation to the underlying and overlying formations.

Am. Jour. Sci., 3d series, vol. 38, pp. 440–445. 1889.

An account of its characteristics and relations in various districts in Texas and northern Mexico, and discussion of its stratigraphic range, equivalency, history, and extent.

—— On the Permian formation of Texas.

Am. Naturalist, vol. 23, pp. 109–128, pl. (February, 1889).

Discussion of faunal and stratigraphic relations and range; brief description of its several members, estimates of thickness, dip, and extent, characteristics and relations of associated formations, and review of evidence and opinions bearing on the identity and equivalency of the Permian in North America.

—— On invertebrate fossils from the Pacific coast.

U. S. Geol. Survey, Bull., vol. 8, pp. 433–532, pls. I–XIV. No. 51. 1889.

Abstract. Am. Geologist, vol. 5, pp. 109–110, ½ p. 1890.

The paper consists of five parts: I. New fossil mollusca from the Chico-Téjon series of California, which includes a discussion of the stratigraphic and faunal relation of the series. II. Equivalents of the Chico-Téjon series in Oregon and Washington; a description of a number of new or little-known localities. III. Cretaceous fossils from Vancouver Island region, including some remarks on the faunal relations of the Vancouver group. IV. Molluscan fauna of the Puget group; includes some general remarks on the geology of the group, its history, extent, and faunal and floral relations. V. Mesozoic mollusca from the southern coast of the Alaskan peninsula, including some remarks on the horizon of the containing beds.

—— The North American Mesozoic.

Science, vol. 14, pp. 160–166. 1889.

Nature, vol. 40, p. 557, 12 lines. 1889.

Abstracts of address to Am. Assoc. Adv. Science, 1889.

WHITE, C. D. Carboniferous glaciation in the southern and eastern hemispheres, with some notes on the Glossopteris flora.

Am. Geologist, vol. 3, pp. 299–330. 1889.

Sets forth a summary of the evidence of an early Carboniferous glacial epoch in the region bordering the Indian Ocean in Asia Africa, and Australia, and reviews the discussions of its date and extent, the correlation of the terranes by which it is represented in different regions, the origin and history of the Glossopteris flora, and the evidence of an Africa-India-Australian continent.

WHITE, I. C. Rounded bowlders at high altitudes along some Appalachian rivers.

Am. Jour. Sci., 3d series, vol. 34, pp. 374–381. 1887.

A discussion of the history recorded in the bowlder deposits and terraces, especially in connection with the existence of a glacial ice dam in the Ohio. Discusses the relations and significance of bowlder deposits along the upper Ohio, the Kanawha, the Pittsburg regions, the Potomac, and the James; the bowlder and clay-covered divides of the Teazes valley near Charleston and Pittsburg and McKeesport, Pennsylvania; the terraces of the Monongahela and Youghiogheny, the variations in altitude of these bowlder and terrace deposits, and the origin of the high-level deposits along the Cheat River of West Virginia.

WHITEAVES, J. F. Notes on some Mesozoic fossils from various localities on the coast of British Columbia, for the most part collected by Dr. G. M. Dawson in the summer of 1886.

Canada, Geol. and Nat. Hist. Survey, Report, 1886, part B, pp. 108–114. Appendix 1. 1887.

Includes mention of localities and some suggestions in regard to horizons indicated by the fossils.

WHITFIELD, J. Edward. [Analyses of volcanic dusts.]

U. S. Geol. Survey, Bull., vol. 7, p. 141, ½ p. No. 42. 1887.

From Marsh Creek valley, Idaho, Little Sage Creek, Montana, and Devil's pathway, Montana.

—— Coal from Jefferson County, West Virginia.

U. S. Geol. Survey, Bull., vol. 7, p. 146, ½ p. No. 42. 1887.

Analysis.

—— Coal from Walnut Cove, Stokes County, North Carolina.

U. S. Geol. Survey, Bull., vol. 7, p. 146, ½ p. No. 42. 1887.

Analysis.

WHITFIELD, R. P. New Jersey Cretaceous.

Am Naturalist, vol. 21, pp. 66–69. 1887.

General review of stratigraphy and faunal relations of the Cretaceous and Eocene, and discussion of the equivalency of the former with members in the upper Missouri section.

—— [On the use of the term "Quaternary."]

International Congress of Geologists, Am. Committee Reports, 1888, F, pp. 15–16, ½ p.

WHITFIELD, R. P.—Continued.

Am. Geologist, vol. 2, pp. 281–282. 1888.

Consideration of its taxonomic value.

—— Observations on some imperfectly known fossils from the Calciferous sandrock of Lake Champlain, and descriptions of several new forms.

Am. Museum Nat. Hist., Bull., vol. 2, pp. 41–63, plates VII–X. 1889.

Preceded by a brief description of the relations near Plattsburg, New York.

—— Note on the faunal resemblance between the Cretaceous formations of New Jersey and those of the Gulf States.

Am. Museum Nat. Hist., Bull., vol. 2, pp. 113–116. 1889.

Parallel lists of species from Alabama, Mississippi, Texas, and Dakota, and comments on the faunal relations.

WHITING, H. A. Mono County.

California, Eighth Report of State Mineralogists, pp. 352–401. 1888.

Includes incidental references to geologic relations at various localities and to petrographic features of some of the rocks.

WHITTLE, Charles Livy. The intrusive and extrusive Triassic trap sheets of the Connecticut valley. See **DAVIS**, William Morris, and.

WILLIAMS, George H. On a plan proposed for future work upon the geological map of the Baltimore region.

Johns Hopkins Univ. Circular, No. 59, pp. 122–123. 1887.

Statement of scope.

—— Rutil nach Ilmenit in verändertem Diabas. Pleonast (Hercynit) in Norit von Hudson-Fluss. Perowskit in Serpentin (Peridotit) von Syracuse, New York.

Neues Jahrbuch, 1887, Band 2, ss. 263–267.

Describes micropetrography of diabase from Big Quinnesec Falls, Menominee River; the norite of the Cortlandt series, and the serpentine of Syracuse, the origin of which is also briefly discussed.

—— The norites of the "Cortlandt series" on the Hudson River near Peekskill, New York.

Am. Jour. Sci., 3d series, vol. 33, pp. 135–144, 191–199. 1887.

Abstract, Neues Jahrbuch, 1887, Band 2, ss. 316–317.

After a review of the distribution of hypersthene rocks in general, describes and discusses the micropetrography, occurrence

WILLIAMS, George H.—Continued.

and some structural relations of the "norite proper," "hornblende norite," "mica norite," "hyperite," or "augite norite," "pyroxenite" and their graduations.

—— Holocrystalline granitic structure in eruptive rocks of Tertiary age.

Am. Jour. Sci., 3d series, vol. 33, pp. 315–316, 1887.

Notice of some of Stelzner conclusions in his memoir on "The Geology of the Argentine Republic." Incidentally refers to the nature of the "Nevadite" of von Richthofen and discusses the relations of structure in rock masses to the conditions under which they solidify.

—— On the serpentine (peridotite) occurring in the Onondaga salt group at Syracuse, New York.

Am. Jour. Sci., 3d series, vol. 34, pp, 137–145. 1887.

Abstracts by author, Science, vol. 9, pp. 137–145, 1887; Neues Jahrbuch, 1888, Band 1, ss. 80–81.

Describes the occurrence of the rock and its chemic and mineralogic constituents. Discusses its alteration from peridotite and its close resemblance to the dikes of Elliott County, Kentucky.

—— The gabbros and associated hornblende rocks occurring in the neighborhood of Baltimore, Maryland. U. S. Geological Survey, Bull. No. 28.

Abstract, Geol. Mag., 3d decade, vol. 4, pp. 87–88. 1887.

—— Some examples of the dynamic metamorphism of the ancient eruptive rocks on the south shore of Lake Superior. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 36, pp. 225–226. 1888.

Description of certain modifications which rocks undergo when subjected to the action of mountain-making forces.

—— The gabbros and diorites of the "Cortlandt series" on the Hudson River near Peekskill, New York.

Am. Jour. Sci., 3d series, vol. 35, pp. 438–448. 1888.

Abstract, Am. Naturalist, vol. 22, p. 929, ½ p. 1888.

References to occurrence and relation to each other, and petrographic description.

—— The contact metamorphism produced in the adjoining mica schists and limestones by the massive rocks of the "Cortlandt series" near Peekskill, New York.

WILLIAMS, George H.—Continued.

Am. Jour. Sci., 3d series, vol. 36, pp. 254–269. pl. VI. 1888.

Abstracts, Johns Hopkins Univ. Circulars, vol. 7, pp. 63–65, No. 65, 1888; Am. Naturalist, vol. 22, pp. 1020–1021, ½ p., 1888.

Mainly petrographic. Describes contact relations at Cruger's Station and on the southern end of Verplanck's Point. Résumé of evidence of the eruptive nature of the massive members of the Cortlandt series and references to conditions of solidification, and location of the center of eruptive action.

—— [Subdivision of Archean, nature of oldest crystalline schists, origin of serpentine, and use of term "Taconic."]

International Congress of Geologists, Am. Committee Reports, 1888, A, pp. 67–68.

—— On the use of the term "Taconic."

International Congress of Geologists, Am. Committee Reports, 1888, B, p. 17, 3 lines.

Am. Geologist, vol. 2, p. 207. 1888.

Expression of opinion.

—— Geology of the Baltimore region.

Johns Hopkins Univ. Circulars, vol. 7, p. 73, ½ col. No. 65. 1888.

Refers to the sequence of the eruptives.

—— Progress of the work on the Archean geology of Maryland.

Johns Hopkins Univ. Circulars, vol. 7, pp. 61–63. No. 65. 1888.

General sketch of Maryland geology and description of the relations of the gneisses and various eruptives in the Baltimore region and northward to the Pennsylvania line.

—— Geology of Fernando de Noronha, Part II, petrography.

Am. Jour. Sci., 3d series, vol. 37, pp. 178–189. 1889.

Abstract, Am. Naturalist, vol. 23, p. 522, ½ p. 1889.

Petrographic description of specimens of phonolites, trachytes, and andesites.

—— Contributions to the mineralogy of Maryland.

Johns Hopkins Univ. Circulars, vol. 8, pp. 99–100. No. 75. 1889.

Includes reference to the occurrence and composition of an ottrelite rock in Frederick County.

WILLIAMS, H. S. Methods of instruction in general geology.

Am. Naturalist, vol. 21, pp. 616–626. 1887.

—— On the fossil faunas of the upper Devonian. The Genesee section, New York.

U. S. Geol. Survey, Bull., vol. 6, pp. 481–502, pls. I–IV. No. 41. 1887.

WILLIAMS, H. S.—Continued.

Discussion of the paleontologic and stratigraphic relations, equivalency, and range of the members of the upper Devonian and base of the lower Carboniferous in southern New York, northern Pennsylvania, and Ohio. Detailed description of stratigraphy and fauna at various localities from Genesee County, New York, to McKean County, Pennsylvania.

—— On the different types of the Devonian system in North America.

Am. Jour. Sci., 3d series, vol. 35, pp. 51–59. 1888.

Abstracts, Nature, vol. 37, p. 358, 11 lines, 1888; Am. Assoc. Adv. Science, Proc., vol. 36, pp. 207–208, ¾ p. 1888.

Résumé of the more prominent features and discussion of the paleontologic and stratigraphic relations of the Devonian formations in the several areas.

—— Report of the subcommittee on the upper Paleozoic (Devonic).

International Congress of Geologists, Am. Committee Reports, 1888, C, pp. 31.

Am. Geologist, vol. 2, pp. 225–239. 1888.

Review by Jules Marcou, Am. Geologist, vol. 3, pp. 60–61, ¾ p. 1889.

A general review of the distribution, taxonomy, and nomenclature of the Devonian members of North America.

—— On the relation of the Devonian faunæ of Iowa.

Am. Geologist, vol. 3, pp. 230–233. 1889.

Discussion of the faunal relations, and stratigraphy and equivalency of the Iowa Devonian.

—— The use of fossils in determining the age of geologic terranes. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 37, p. 206, ¾ p. 1889.

Discusses the value and limitation of paleontologic correlations.

—— [Comparision of cis- with trans-Atlantic formations.]

Nature, vol. 40, p. 557, ½ col. 1888.

Abstract of paper read to American Association, 1889.

Faunal relations of Devonian of England and America.

WILLIAMS, S. G. Note on the lower Helderberg rocks of Cayuga Lake.

New York, Sixth Report of the State Geologist, 1886, pp. 10–12. 1887.

Notice of additional discoveries of fossils. Repeats his opinion that the "Salina and lower Helderberg are merely different phases of one geological period, deposited under very different conditions indeed, but to a great extent contemporaneously."

WILLIAMS, S. G.—Continued.

—— The Tully limestone, its distribution, and its known fossils.

New York, Sixth Report of the Geologist, 1886, pp. 13–29. Map. 1887.

Describes its line of outcrop, constituents, thickness, structure, and fossils. Accompanied by a map of its outcrop.

WILLIS, Bailey. Changes in river courses in Washington Territory due to glaciation.

U. S. Geol. Survey, Bull., vol. 6, pp. 473–480, 4 plates. No. 40. 1887.

Discussion of the agency of lava flows and glaciers in diverting a portion of the course of the Columbia River. Accompanied by a geologic map indicating the formations along a line of reconnaissance, and hachured maps showing preglacial channel of the Similkameen River, the lower valley of the Okinakane River, and Columbia River from the latter to Lake Chelan.

—— Topography and structure in the Bays Mountains, Tennessee.

School of Mines Quarterly, vol. 8, pp. 242–252. 1887.

Describes their structure, topography, and drainage, and discusses the relations of drainage and topography to structure, and the time and extent of Appalachian uplift.

[——] [Absence of Sierra Nevada structure in northern Washington Territory.]

Washington, Phil. Soc., Bull., vol. 9, p. 8, ¼ p. 1887.

States that the eastern face of the Cascade Range is not determined by a great fault.

—— The marble of Hawkins County, Tennessee.

School of Mines Quarterly, vol. 9, pp. 112–123. 1888.

Description of a bed of Trenton marble, and the great fault by which it is cut off from the adjoining Cambrian rocks.

—— Mount Rainier and its glaciers.

Washington, Phil. Soc., Bull., vol. 10, p. 10, ¼ p. 1888.

Brief mention of the paper, and statement in regard to the relations of Mounts Rainier and Shasta as points of volcanic activity.

—— Round about Asheville.

National Geogr. Mag., vol. 1, pp. 291–300. Map. 1889.

Classification of the topographic characteristics of the western North Carolina-East Tennessee region, and discussion of evidence and history of successive stages of elevation and base leveling.

WINCHELL, Alexander. Report of geological observations made in north-

WINCHELL, Alexander.—Continued.

eastern Minnesota during the season of 1886.

Geol. and Nat. Hist. Survey of Minn., 16th Report, 1886, pp. 7-206. Map. 1887.

Field notes of work in region north of the western part of Lake Superior. Describes and figures many details of structure, rock texture, and distribution, volcanism, vein stones, etc., in the crystalline and metamorphic series. In a summary of observations (p. 172) gives a general description of the region, and discusses the structural and stratigraphic relations, extent, equivalency, modifications, variations, origin, and geologic history of the formations. Reviews Lawson on the Keewatin series, and on gneissic foliation. Notices some glacial phenomena in the region. Accompanied by a folded colored geologic map, in part, by N. H. Winchell.

—— Unconformability between the Animikie and the Vermilion series.

Am. Jour. Sci., 3d series, vol. 34, p. 314. 1887.

"The Animikie flint schists dipping, 5° S. have been traced by me to within seven feet of sericitic argillites of the Vermilion series dipping about 67° NE."

—— The unconformities of the Animikie in Minnesota.

Am. Geologist, vol. 1, pp. 14–24. 1888.

Reference to characteristics, relations, distribution, and equivalency of the Animikie, and description and discussion of relations in northern Minnesota and some adjacent portions of Canada.

—— Some effects of pressure of a continental glacier.

Am. Geologist, vol. 1, pp. 139–143. 1888.

Discussion of relations of crustal deformation to the great lava outflows of the far West, and to post-glacial uplift of shore lines in the Atlantic coast region.

—— The Taconic question.

Am. Geologist, vol. 1, pp. 347–363. 1888.

Review of literature, and discussion of the grounds of the opponents of the Taconic system, and the nomenclature of the lower Palæozoic.

—— Geology as a means of culture.

Am. Geologist, vol. 2, pp. 44–51, 100–114. 1888.

—— [On the use of the term "Taconic."]

International Congress of Geologists, Am. Committee Reports, 1888, B, pp. 12–13.

Am. Geologist, vol. 2, pp. 202–203. 1888.

Discussion of its applicability.

—— [On the nomenclature of the Tertiary, and the faunal relations, and designation of the Quaternary.]

WINCHELL, Alexander.—Continued.

International Congress of Geologists, Am. Committee Reports, 1888, F, pp. 16–17, ¾ p.

Am. Geologist, vol. 2, pp. 282–283. 1888.

Discusses the taxonomic value of the Lyellian divisions, and the term "Quaternary."

—— Report of a geological survey in Minnesota during the season of 1887, embracing comparative observations in some other regions.

Minnesota, Geol. and Nat. Hist. Survey, 16th Report, pp. 133–391. 1888.

Description and discussion of relations in northeastern Minnesota, preceded by an account and discussion of observations in the original Huronian in Canada, and in Northern Michigan, and Wisconsin.

—— Systematic results of a field study of the Archean rocks of the northwest. [Abstract.]

Am. Assoc. Adv. Science, vol. 37, pp. 205–206, ½ p. 1889.

Abstract, Science, vol. 12, p. 100, 12 lines. 1888.

Summary statement of stratigraphic succession and equivalency of the crystalline series of the Northwest.

—— Conglomerates enclosed in gneissic terranes.

Am. Geologist, vol. 3, pp. 153–165. 1889.

Describes pebble-bearing gneisses in the region northwest of Lake Superior, discusses the bearing of their occurrence on the origin and history of the gneiss, and cites other instances of conglomeritic crystalline rocks in New England and in Europe.

[——] Rejoinder to Dr. Lawson [on rock foliation and sedimentation].

Am. Geologist, vol. 3, pp. 193–195. 1889.

Discussion of some conditions of metamorphism, and citation of English investigations bearing on the question.

—— Two systems confounded in the Huronian.

Am. Geologist, vol. 3, pp. 212–214. 1889.

Review of Bonney. "Notes on a part of the Huronian series in the vicinity of Sudbury, Canada." Discusses the age and equivalency of the beds described by Bonney, and the correlation of the post-Laurentian series in the Sudbury region with the Huronian and associated series in the Lake Superior district.

—— Conglomerates enclosed in gneissic terranes.

Am. Geologist, vol. 3, pp. 256–261. 1889.

Discusses the bearing of the occurrence of pebbles in crystalline rocks of various ages, including the Laurentian, on the clastic origin of some of the Laurentian members.

WINCHELL, Alexander—Continued.

—— On the Archean. See **FRAZER**, Report on Archean.

WINCHELL, H. V. Partial report of observations made by.

Minnesota, Geol. and Nat. Hist. Survey, Fifteenth Report, 1886, pp. 403–419. 1887.

On crystalline rocks of a portion of northeastern Minnesota.

—— Report of observations made during the summer of 1887.

Minnesota, Geol. and Nat. Hist. Survey, Sixteenth Report, pp. 395–478, map. 1888.

Description of relations and characteristics of crystalline rocks along various routes in northwest Minnesota. References to Cretaceous outliers.

—— The diabasic schists containing the jaspilyte beds of northeastern Minnesota.

Am. Geologist, vol. 3, pp. 18–22. 1889.

Description and discussion of relations of the massive and of schistose basic series and their siliceous and ferruginous associates.

—— Report of field observations made during the season of 1888 in the iron regions of Minnesota.

Minnesota, Geol. and Nat. Hist. Survey, Seventeenth Report, pp. 77–145. 1889.

Notes on region east of Tower. Discussion of the relations of the several formations, pages 128–135.

—— [Professor Irving and the Keewatin series, and the origin and horizon of the iron ores of the Vermilion Lake series.] See **WINCHELL**, N. H. and H. V.

—— On a possible chemical origin of the iron ores of the Keewatin in Minnesota. See **WINCHELL**, N. H., and H. V.

WINCHELL, N. H. Geological report.

Minnesota, Geol. and Nat. Hist. Survey, Fifteenth Report, 1886, pp. 211–399, map. 1887.

Detailed description of Vermilion Lake iron region and vicinity, and discussion of the structural relations, stratigraphy, equivalency, age, extent, origin, etc., of the several formations and of the "jaspilyte rock." Gives list of some glacial striæ. Describes some features of the Mayhew Lake titaniferous iron-ore district. Accompanied by a folded, colored, geologic map.

—— Notes on the classification and nomenclature for the American Committee of the International Geological Congress, March, 1888.

WINCHELL, N. H.—Continued.

American Naturalist, vol. 21, pp. 693–700. 1887.

After stating the present condition of the Taconic question, discusses the history, application, and equivalency of the terms "Taconic," "Primordial," and "Cambrian," showing that "Taconic" was prior to "Cambrian" under the same conditions of application, and was originally applied with equal error. It is urged that "Taconic" should be retained for the first fauna and "Cambrian" for the second, in accordance with the purpose of their authors. Discusses the subdivisions of the Archean and the use of the term.

—— The granite and quartzite contact of the Aurora mine, Gogebic iron range, at Ironwood, Michigan. [Abstract.]

Am. Assoc. Adv. Science, Proc., vol. 36, p. 211, ½ p. 1888.

Discusses the nature and origin of the granite, and refers it to the Huronian.

—— The Animikie black slates and quartzites, and the Ogishke conglomerate of Minnesota, the equivalent of the "original Huronian."

Am. Geologist, vol. 1, pp. 11–14. 1888.

Includes a review of the characteristics of the original Huronian, and a table suggesting the equivalency of the several members with similar rocks in Minnesota and Wisconsin.

—— Some objections to the term Taconic considered.

Am. Geologist, vol. 1, pp. 162–173. 1888.

Discussion of the status of the term and discussion of the objections advanced against its adoption.

—— A great primordial quartzite.

Am. Geologist, vol. 1, pp. 173–178. 1888.

Correlation of Cambrian quartzites of the Taconic region, the Potsdam sandstone of New York, the Huronian quartzites of Minnesota and Wisconsin, the "Potsdam" sandstone of the Black Hills of Dakota, and the eastern sandstones of Michigan.

[——] Note [on small outliers of Cretaceous in Minnesota].

Am. Geologist, vol. 2, p. 334, ½ p. 1888.

References to localities and characteristics.

—— Report of the subcommittee on the lower Paleozoic.

International Congress of Geologists, Am. Committee Reports, 1888, B, pp. 37.

Am. Geologist, vol. 2, pp. 193–224. 1888.

Discussion of nomenclature, especially in regard to the use of the terms "Taconic" and "St. Croix." Includes extracts of letters from J. D. Dana, S. W. Ford, James Hall, C. H. Hitchcock, Alexander Winchell, J. S. Newberry, G. H. Williams, J. W. Dawson, A. R. C.

WINCHELL, N. H.—Continued.

Selwyn, B. K. Emerson, Joseph Le Conte, James Macfarlane, S. F. Emmons, A. Hague, W. P. Blake, and C. E. Dutton, and synopsis of conclusions by C. D. Walcott on the "Taconic system of Emmons," which is also reviewed.

—— Preface.

Minnesota, Geology of, Final Report, vol. 2, pp. 13–24. 1888.

Discussion of some of the stratigraphic relations and equivalency of members of the Cambrian in the Minnesota and Mississippi valleys. Reference to Cretaceous areas and glacial history.

—— The geology of Wabasha County.

Minnesota, Geology of, Final Report, vol. 2, pp. 1–19, map. 1888.

Description of Cambrian and Trenton areas and the drifts and terraces. Reference to the probable occurrence of Cretaceous. Discussion of the history of some drainage and topographic features. Accompanied by a colored geologic map.

—— The geology of Goodhue County.

Minnesota, Geology of, Final Report, vol. 2, pp. 20–61, map. 1888.

Description of Cambrian, Trenton, Cretaceous, drifts and terraces. List of fossils. Discussion of relation of some drainage features, ancient and modern, extent of Cretaceous, origin of some topographic features, and history of some of the drifts. Accompanied by a colored geologic map.

—— The geology of Dakota County.

Minnesota, Geology of, Final Report, vol. 2, pp. 62–101, map. 1888.

Description of lower Silurian and Cambrian areas, drifts, faults, terraces, gravel plains, remains of ancient drainage systems, Cretaceous outcrops, and the glacial history of the region. Accompanied by a colored geologic map.

—— The geology of Hennepin County.

Minnesota, Geology of, Final Report, vol. 2, pp. 264–344, map, pls. A[1], M–Z. 1888.

Descriptions of Trenton limestone, St. Peter sandstone, and Cretaceous outcrops, and the drifts and terraces. Records of artesian wells. Review of descriptions of St. Anthony's Falls, and discussion of their history and rate of recession. Accompanied by a colored geologic map.

—— The geology of Ramsey County.

Minnesota, Geology of, Final Report, vol. 2, pp. 345–374, map. 1888.

Description of Trenton and St. Peter sandstone and the drifts. Discussion of origin of certain topographic features, the extent and stratigraphic relations of some of the members of the rock formations, and the equivalency of some of the beds met with in the artesian wells. Accompanied by a colored geologic map.

WINCHELL, N. H.—Continued.

—— The geology of Washington County.

Minnesota, Geology of, Final Report, vol. 2, pp. 375–398, map. 1888.

Description of Trenton limestone, St. Peter sandstone, and lower magnesian limestone areas, the drifts, terraces, an anticlinal and faults in the Cambrian, and an unconformity between the lower magnesian and the St. Peter sandstone. Accompanied by a colored geologic map.

—— Report [original Huronian, iron-bearing rocks in Marquette and Gogebic region, and northeastern Minnesota].

Minnesota, Geol. and Nat. Hist. Survey, Sixteenth Report, pp. 13–129. 1888.

Description of various localities, and discussion of structural relations, stratigraphy, genesis, and equivalency of the several pre-Cambrian members. List of directions of glacial striæ.

—— Natural gas in Minnesota.

Minnesota, Geol. and Nat. Hist. Survey, Bull. No. 5, pp. 39. St. Paul, 1889.

Includes records of deep borings near Freeborn, Albert Lea, Mankato, Stillwater, Moorhead, and Duluth, and some comments on the geologic horizon and relations of the beds pierced.

—— The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved.

Minnesota, Geol. and Nat. Hist. Survey, Seventeenth Report, pp. 5–74. 1889.

Review by J. D. Dana, Am. Jour. Sci., 3d series, vol. 39, pp. 67–68, ¾ p. 1890.

Abstract, Am. Geologist, vol. 5, pp. 59–60. 1890.

A general review and discussion of the stratigraphy, history, and relations of formations from the Laurentian to the St. Croix sandstone.

[——] List of American publications between 1872 and 1889 that have some relation to the crystalline rocks of the Northwest.

Minnesota, Geol. and Nat. Hist. Survey, Seventeenth Report, pp. 233–265. 1889.

—— Notice of the discovery of Lingula and Paradoxides in the red quartzite of Minnesota.

Minnesota, Acad. Sci., Bull., vol. 3, part 1, pp. 103–105. 1889.

Description of the remains, and brief reference to the relations and age of the formation, and its representatives elsewhere.

WINCHELL, N. H.—Continued.

—— Some thoughts on eruptive rocks, with special reference to those of Minnesota.

Am. Assoc. Adv. Sci., Proc., vol. 37, pp. 212–221. 1889.

Reviews classification and relations of eruptive rocks in general, advances hypothesis as to the genesis of acid and of basic eruptives, and gives a résumé of the stratigraphic relations and eruptive contents of the several crystalline rock series of the Northwest.

—— Methods of stratigraphy in studying the Huronian.

Am. Geologist, vol. 4, pp. 342–357. 1889.

Reviews the Huronian system, and discusses its taxonomy, relations to Laurentian, correlation outside of the type area, stratigraphic range and characteristics, and past and present methods of research in this connection.

—— On the Archean. See **FRAZER**. Report on Archean.

—— and **WINCHELL**, H. V. [Professor Irving and the Keewatin series, and the origin and horizon of the iron ores of the Vermilion Lake series.]

Am. Geologist, vol. 4, pp. 383–386. 1889.

Review of Irving's writings in this connection, including references to the distribution, equivalency, and sideritic contents of iron-bearing series of Minnesota.

—— —— On a possible chemical origin of the iron ores of the Keewatin in Minnesota.

Am. Geologist, vol. 4, pp. 291–300. 1889.

Point out the differences in characteristics and relations of the Keewatin and Huronian ores. Discuss the history of the Keewatin formation and advance a hypothesis as to the genesis of its siliceous and ferruginous members.

WINSLOW, Arthur. The Lehigh River cross-section, measured, mapped, and described in detail. Edited by J. P. Lesley.

Pennsylvania, Report of Geol. Survey, 1886, part 4, pp. 1331–1371, sheets 1–5, in atlas. 1887.

Detailed descriptions of stratigraphy and structure. Discussion of the stratigraphic range of some of the members of Nos. IX and X. Accompanied by maps and cross and columnar sections.

—— A preliminary report on a portion of the coal regions of Arkansas.

Arkansas, Geol. Survey, Report for 1888 vol. 3, pp. 1–92, map. 1888.

WINSLOW, Arthur—Continued.

General account of distribution, stratigraphy, and structure. Descripiton of prominent localities. Analyses. Economic. Geologic map.

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Archean rocks of the Northwest, WINCHELL, A.

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Irving and Chamberlin on Lake Superior sandstones, AM. GEOLOGIST.

loess and clays, analyses, RIGGS.

Penokee Gap region, WINCHELL, A.

Quaternary of northwestern Wisconsin, CHAMBERLIN.

raised beaches of Lake Michigan, LEVERETT.

Report—Lake Superior division, U. S. Geol. Survey, IRVING.

Report—Glacial division, U. S. Geol. Survey, CHAMBERLIN.

rock from Penokee iron ranges, analysis, RIGGS.

Taconic system, MILLER.

Wisconsin Academy of Sciences, Arts, and Letters, Transactions, vol. 7.

Raised beaches of Lake Michigan, LEVERETT.

WOODWARD, Henry. On the discovery of *Turrilepas* in the Utica formation (Ordovician) of Ottawa, Canada.

Geol. Magazine, decade III, vol. 6, pp. 271–275. 1889.

Includes stratigraphic section of the beds at Rifle Range, near Ottawa, by H. M. Ami.

WOODWARD, R. S. On the form and position of the sea level with special reference to its dependence on superficial masses symetrically disposed about a normal of the earth's surface.

U. S. Geol. Survey, Bull., vol. 8, pp. 87–172, No. 48. 1888.

Incidentally considers certain geologic causes of earth-crust deformation.

WOOLBRIDGE, C. W. The river-lake system of western Michigan.

Am. Geologist, vol. 1, pp. 143–146. 1888.

Description of relations and discussion of origin and history.

—— The post-glacial geology of Ann Arbor, Michigan.

Am. Geologist, vol. 2, pp. 35–39. 1888.

Description of delta deposits and shore lines, and discussion of their history.

WOOLMAN, Lewis. Geological result of the boring of an artesian well at Atlantic City, New Jersey.

Philadelphia, Acad. Sci., Proc., 1887, pp. 339–342

Description of 1,121-foot record, lists of fossils and statement in regard to horizons of the Tertiary beds passed through.

—— [Fossiliferous Cretaceous limestone from near Clementon, New Jersey.]

Am. Naturalist, vol. 23, p. 544, 3 lines. 1889.

Notice of occurrence and fossils.

WOOSTER, L. C. The coal measures of Kansas.

Science, vol. 12, p. 119, ½ col. 1888.

Eng. and Mining Jour., vol. 46, p. 240, ½ col. 4°. 1888.

Describes 2,000-foot bore-hole entirely in coal measures and discusses the conditions under which the coal measures were deposited.

—— The limit of drift [Kansas].

Science, vol. 12, p. 132, ½p. 1888.

Calls attention to some glaciated bowlders and briefly discusses their mode of transportation.

WRIGHT, G. Frederick. Notes on the glaciation of the Pacific coast.

Am. Naturalist, vol. 21, pp. 250–256. 1887.

Describes results of glaciation along Northern Pacific Railroad west from Bismarck, in the region about Puget Sound, and glaciers and evidence of glacial action up the coast. Discusses the glacial history of the Puget Sound region.

—— The Muir glacier.

Am. Jour. Sci., 3d series, vol. 33, pp. 1–18. 1887.

WRIGHT, G. Frederick—Continued.

Sci. Am., Supt., vol. 23, pp. 9252–9254. No. 579. 1887.

Description of the glacier, its moraines, its motion, evidence of its retreat, associated drift and rock formations, striæ, and buried forest and other glaciers in its vicinity.

—— ["The ice age in North America."]

Am. Geologist, vol. 1, p. 68, ½ p. 1888.

Notice of lecture to Lowell Institute. Reference to nature of evidence indicative of two glacial epochs.

—— On the age of the Ohio gravel beds.

Boston Soc. Nat. Hist., Proc., vol. 23, pp. 427–436. 1888.

Extract, "Preglacial man in Ohio," Ohio Arch. and Hist. Quart. December, 1887.

Describes the relations of the Trenton gravels and of deposits of similar origin in the valley of the Little Miami in Ohio, and discusses the date of their deposition in glacial times.

—— The ice age in North America, and its bearings upon the antiquity of man. 640 pages, maps. New York, 1889.

Abstract, Popular Science Monthly, vol. 35, pp. 557–560. 1889.

Review, W. M. Davis; Science, vol. 14, pp. 118–119. 1889; Appalachia, vol. 6, pp. 72–73. 1890.

I. What is a glacier? II. Existing glaciers on the Pacific coast. III A month with the Muir glacier. IV. Glaciers of Greenland. V. Glaciers in other parts of the world. VI. Signs of glaciation. VII. Boundary of the glaciated area in North America. VIII. Depth of ice during the glacial period. IX. Terminal moraines. X. Glacial erosion and transportation. XI. Drumlins. XII. Preglacial drainage. XIII. Drainage during the glacial period. XIV. Kames. XV. Glacial dams, lakes, and waterfalls. XVI. The loess. XVII. Flight of plants and animals during the glacial period. XVIII. Europe during the glacial period. XIX. The cause of the glacial period. XX. The date of the glacial period. XXI–XXII. Man and the glacial period. Appendix: A. Probable causes of glaciation. B. Chalmers on the glaciation of eastern Canada.

—— The age of the Philadelphia red gravel.

Boston Soc. Nat. Hist., Proc., vol. 24, pp. 152–157. 1889.

Discussion of the age and condition of deposition of the Columbia formation, and incidentally considers the origin of some high-level Columbia gravels in the Susquehanna valley.

—— [Image from deep well at Nampa, Idaho.]

Am. Geologist, vol. 4, pp. 387–388. 1889.

WRIGHT, G. Frederick—Continued.
Includes record of 320-foot well and expression of opinions in regard to the age of the beds in which the image was found.

—— The glacial boundary in southeastern Dakota. [Abstract.]

Am. Assoc. Adv. Sci., Proc., vol. 37, pp. 208–212. 1889.
An account of the glacial deposits, moraines, and topographic characteristics of the region, and discussion of its glacial history.

—— Chipped implement in the drift, Jackson County, Illinois. See **CRESSON**, Hilborne T.

WYATT, Francis. The development of the American chemical industry.—Salt.

Eng. and Mining Jour., vol. 44, pp. 411, 432–433, 448–449. 1887.
Description of salt deposits and borings in Michigan and New York.

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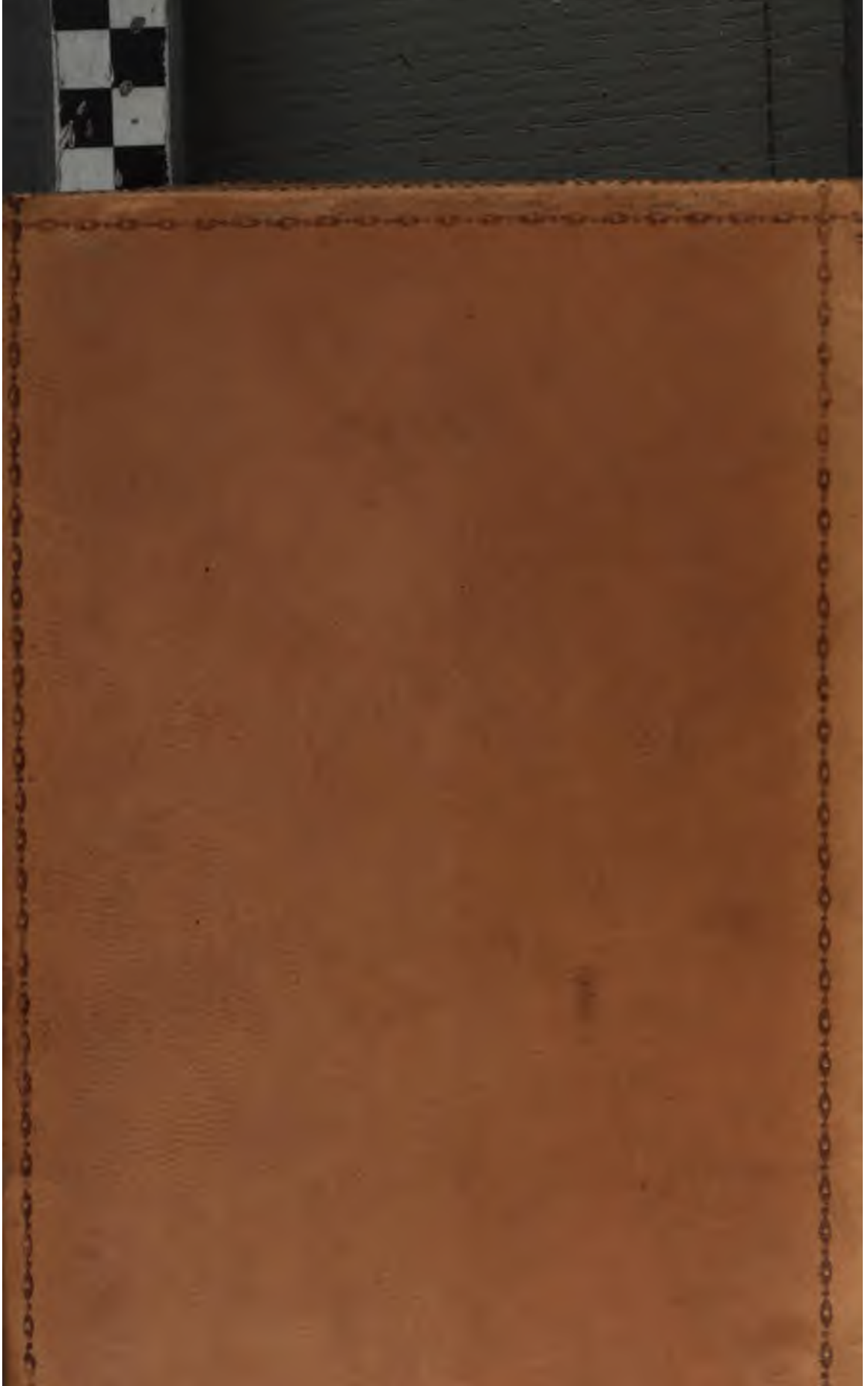
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